Evaluation of UAS Class and EO Sensor Payload Type for Applications in Hostage Crisis Missions

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Abstract: Donohue V. (2014). Evaluation of UAS class and EO sensor payload type for applications in hostage crisis missions. International Journal of Unmanned Systems Engineering. 2(1): 1-8. Law Enforcement entities are tasked with ensuring the safety of citizens to the best of their ability. They use every advantage at their disposal to capture and restrain criminals while reducing the risk to civilians. This ability is often limited by the constraints of slim and shrinking budgets. Departments with larger budgets and greater flexibility have historically taken advantage of airborne assets, most often helicopters, which provide a tremendous advantage against criminals due to enhanced surveillance, pursuit, and capture capability. The latest technological advancements in remote electronic sensing, along with major strides in aircraft automation and miniaturization, have allowed a surge in the implementation of Unmanned Aircraft Systems (UAS) in Law Enforcement missions. This paper discusses the use of UAS by Law Enforcement in a hostage crisis situation. A scenario is presented and a Concept of Operations (CONOPS) is developed to thoroughly detail the mission goal, strategy and tactics. The class of UAS appropriate for the mission, including Micro Air Vehicles and small UAS, and a refined selection between fixed wing and rotary wing aircraft are identified. The Draganflyer X6 and the RAPTR rotary wing UAVs are discussed in deciding what system best accomplishes the hostage crisis mission. Electro-optical sensors, including high definition video, low light level TV and infrared sensors, provide superior applicability.

Keywords: ARA Nighthawk CONOPS Draganflyer X6 FLIR Law Enforcement RAPTR sUAS Tactical electronics

1. INTRODUCTION
On Friday, November 1st 2013 at 9:20 am, a “gunman armed with an assault rifle entered a terminal at Los Angeles International Airport ... killed a TSA agent, and penetrated deep into the terminal before he was captured by police”.[1] This sad event is just the latest reminder of the vulnerability of citizens who suddenly get caught in the rampage of an ill or violent person. This situation could have easily turned into a drawn out hostage crisis. Fortunately, it did not. On January 29th 2013, such situation did develop when a 65-year-old war veteran boarded a school bus, killed the driver, and took a five-year-old boy hostage. The kidnapper retreated to an underground bunker where he held the

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boy hostage for a week. When talks with the FBI eventually began to deteriorate, the FBI stormed the bunker, killing the kidnapper and saving the boy.[2] When innocent life is in danger, we want Law Enforcement to use every reasonable means available to them to save people’s lives. During the standoff with the kidnapper, the FBI implemented the newest and best technology available to law enforcement, the Unmanned Aircraft System (UAS). UAS is a formidable asset that is already being implemented in hostage crises and other law enforcement situations. Although domestic Unmanned Aerial Vehicle (UAV) use is strictly curtailed by the FAA, the advantages of UAV usage are inarguable.

The advantages of airborne assets are numerous for law enforcement: rapid deployment to and from a site, expeditious search of a large area, and the ability to track a subject through traffic or in a wooded area. Large police forces have taken advantage of this capability for years with the use of manned helicopters, but the cost is exceedingly high. “Drones could revolutionize police work. Helicopters are expensive to fuel and maintain, and flying them takes specialized piloting skills. By comparison, drones are easy. They cost about 100 times less than a helicopter, and operating a drone costs significantly less per hour.”[3] UAVs get the job done better, cheaper and faster. Small UAVs are now able to provide Law Enforcement with nearly the same eye-in-the-sky capabilities as that of manned aircraft at a fraction of the cost. A police force with a manned aviation department can maintain the same capability by using unmanned systems while saving a large percentage of the budget by converting appropriate missions to small UAS (sUAS) platforms. Even more compelling, small police departments that could never afford a manned aviation department could implement an unmanned aviation division with many of the same benefits at a fraction of the cost.

2. HOSTAGE CRISIS SCENARIO

This study identifies an appropriate UAV platform for a hostage crisis standoff. The UAV’s “capability to maintain surveillance for a long time over targets allows coordination of the intervention forces and warning of the dangers that threaten them. In this way (UAVs) reduced the risks police team members are subjected carrying out missions”. [4] The scenario is as follows: the police are attempting to end a hostage crisis and need to know how many hostages and hostage takers are present, as well as the types of arms that are employed by the hostage takers. Important questions need to be answered regarding the situation and the environment in considering additional mission requirements. Questions include: How many hostage takers are there? Are they traveling (train, car, plane) or are they stationary (in a building)? Are the hostages and hostage takers spread out or located in defined areas? What kind of material is the building or vehicle made out of? What is the environment (day or night, dark or light, inside or outside)? What sensors would be most effective in the given situation? Certain assumptions must be made in order to properly address the specific hostage crisis situation. We assume that the hostage location is a single-family, wooden-framed house in a suburban neighborhood. The time is early evening, before dusk, 45° F with 50% cloud cover.

3. CONCEPT OF OPERATION (CONOPS)

The first task is to gather intelligence on the hostage scene using UAS with appropriate sensors in order to determine the number of people involved, their locations, their role (hostage or hostage taker) and what weapons are being used. With the given scenario, we develop a CONOPS for the mission. The goal of the hostage crisis team is the safe recovery of all hostages with no fatalities and minimal injuries. The strategy of the UAS team is to implement UAS assets to gain such intelligence. The tactics include the use of one or more UAVs to gain intel using electro-optical (EO) systems while remaining covert and relay the intel to the crisis coordinator for use in deploying and managing ground tactical forces. “Reconnaissance, surveillance, and target acquisition (RSTA) is performed without exposing a human to danger; range finding and target designation allow close coordination with supporting air and ground assets while minimizing fratricide and collateral damage.”[5]
The UAS consists of a UAV, Ground Control Station (GCS), UAV pilot and sensor operator. The UAS team deploys from an area clear of trees within a one block radius of the hostage scene which is out of sight and earshot of the scene. The team deploys the UAV from the launch site and the UAV approaches the hostage scene just over trees to within usable sensor range. The sensor operator instructs the pilot to position the UAV in various locations to maximize scene coverage until sufficient intel is attained. The UAV remains covert utilizing stand-off tactics and cover behind trees and obstacles. The engine and propeller noise is masked using lawn mowers and/or leaf blowers. The UAV remains operational during ground tactical operations, relaying real time operational status to the crisis coordinator. Rescue efforts launch a quickly developing dynamic response, involving hostage and taker movement, infiltration of a rescue team and possible weapons exchange. The UAS team continues to update the operation coordinator throughout, identifying hostages, takers, rescue team members, weapons used, men down, while also securing the perimeter. The operation is concluded when the hostage scene is secured and the rescue team account for all hostages, takers, weapons and rescue personnel.

4. UAS CLASS SELECTION

Budgetary constraints are always a concern when implementing any system, so we first consider the smallest UAV in search of the least expensive, sufficiently capable platform that will accomplish the mission. “A good rule of thumb is that the best UAS class is the smallest and most affordable that can satisfactorily perform the desired role”.[6] The smallest UAV is the micro air vehicle, or MAV, which has a maximum physical length of up to 6 inches according to the Defense Advanced Research Projects Agency (DARPA); although manufacturers claim MAVs can have a wing span up to 2.5 feet. Given the small size of the aircraft, an MAV would be an excellent platform to satisfy our tactical requirement for stealth. However, their small size allows for little payload capacity for the sensors required. “MAVs generally weigh less that 0.5 lb, which leaves little provision for avionics or mission systems. MAVs are not steady platforms. Their low mass and slow flight speeds make them particularly sensitive to gusts and turbulence, even with well-designed flight controls”.[6] Although a UAV in the MAV design class might provide a stealthy platform, it would be payload limited and unable to carry the EO sensors needed to fulfill the mission. Thus, an MAV platform is not adequate to fulfill a hostage rescue mission. The next class of UAS available is the small UAS, or sUAS, which range in weight from 1 to 55 lbs. “Systems miniaturization now make sUAS operationally useful, effectively performing missions relegated to much larger systems as late as the 1990s. Lightweight, GPS-based autopilot technologies originally demonstrated on MAVs offer sUAS the ability to carry useful loads. Very small gimbaled camera payloads weighing 1-5 lbs were developed specifically for this class of unmanned aircraft (UA) using new design approaches”.[6] The sUAS is the smallest UAV class that will be able to carry the appropriate sensors and fulfill the hostage rescue mission requirements and is thus an appropriate platform to implement in this situation.

Our next consideration is whether to use a fixed wing or rotary wing aircraft. Since the location is stationary, we do not need to be concerned with speed, either to dash to the location or to chase a moving target. More importantly, the mission requires a UAV with loitering capability, and a UAV that has hovering capacity is more useful than one that circles overhead. A hovering platform provides a stationary position from which to observe events inside the building and discern hostages, who will more likely be stationary, from the hostage takers, who are more likely moving. A fixed wing UAV such as the ARA Nighthawk (Fig. 1) would have few benefits and more liabilities for this situation. One such benefit is the ability to arrive on station quickly. However, this would require a launch site somewhat close to the hostage site and given the suburban location, finding a runway or open field nearby from which to launch may be difficult. Once arriving on site, the Nighthawk would loiter by circling either overhead or at a standoff location. An overhead loiter would allow for the best sensing vantage point, but the platform would always be moving, making it more difficult to discern movement inside the house. In addition, a person of interest, once spotted, may be lost
behind an obscuring object such as a tree, a wall or another person as the Nighthawk circled. Also important is the need for the UAV to remain undetected by the hostage takers. A Nighthawk circling overhead would likely be noticed from engine noise or movement of the aircraft. This would dictate that the Nighthawk loiters sufficiently distant from the scene to remain out of earshot and perhaps even visual range. This decreases the effectiveness of the sensors requiring a compromise between stealth and sensor performance.

![ARA Nighthawk](www.araforcepro.com)

Fig. 1: The ARA Nighthawk
(Photo: www.araforcepro.com)

A rotary wing UAV such as a multi-rotor or helicopter provides a platform that eliminates several of these concerns. It can be launched from any level platform with no runway, requiring only enough space to navigate safely through the trees. Launched from a lawn just out of eyesight, perhaps 100 yards away from the scene, a rotary wing UAV can be on scene within seconds and loiter by hovering just out of eyesight of the takers. A significant concern is alerting the takers through the noise generated by the UAV. Blade rotation noise is audible, but electric powered engines provide quieter operation than gas powered. Research conducted by the Space and Naval Warfare Systems Center found that of the UAV requirements, “The most significant is the requirement to quiet the system. The problem was primarily caused by the engine exhaust noise. This may be even more of a problem for a smaller system depending on small two-cycle engines. High energy density batteries and high efficiency electric motors may help with this problem.”[5] Although noise is a necessary by-product of any airborne asset, a noise generator such as a lawn mower or leaf blower can be used to mask the sound of the propeller blades and engines.

Numerous small multi-copters are specifically designed for use by Law Enforcement entities. One such multi-copter is the Draganflyer X6 (Fig. 2), used by the Sheriff Office of Mesa County, Colorado, which holds one of the few Certificates of Authorization (COA) granted by the FAA to use UAVs. The Draganflyer X6 weighs a mere 4.6 lbs with a payload capacity of 1.1 lb. Such a small payload capacity allows for only one high-definition (HD) camera or one infra-red (IR) camera.
During this research, an expert on the tactical use of UAVs for law enforcement from Tactical Electronics was consulted. His choice of UAV is the RAPTR (Fig. 3) for tactical LE missions. “The RAPTR is a fully autonomous, vertical takeoff and landing (VTOL), small UAS, which primarily serves as a delivery/transport platform for intelligence, surveillance and reconnaissance payloads.” We asked the expert the following question regarding his choice and implementation of the RAPTR.

**Question:** It seems that your UAV of choice is the RAPTR. What advantage does a helicopter have over a quadcopter (which seem ubiquitous and preferred by LE)?

**Answer:** The platform we are using has a larger lifting capability than a quadcopter or other multi-rotor system. Our platform has a basic empty weight of 14.5 lb and is capable of a 15 lb useful load. The payload capability of most multi-rotor systems is measured in ounces. Similarly, our RAPTR platform is capable of autonomous flight out to well beyond line of sight, in inclement weather and can handle winds up to 40 mph. Most multi-rotor systems
cannot fly in these conditions. Quadcopter-type platforms normally require very mild weather, virtually no wind and in most cases must be flown line-of-sight.

The RAPTR is an impressive helicopter with a high useful load capable of carrying a number of sensors at one time and would do well in satisfying the needs of a hostage rescue mission.

4.1 EO Sensor Payload Category
The most important consideration of the mission is in selecting the appropriate sensors. “A UAV may carry and use different sensors, depending upon the size of the aerial platform in question and its maximum takeoff weight (MTOW). The variety of sensors available is large. Smaller UASs typically employ high quality video and digital cameras. These can be accompanied by infrared sensors which ensure observational capabilities at night”. Our mission requires a sensor in the visible band, as well as a Low Light Level TV (LLLTV) or IR sensor. An HD video camera with live feed to a GCS is the minimum requirement for sensing, recording and navigation. An LLLTV may be of some value as the evening sets in, but would only be somewhat helpful in navigating the area during darkness and perhaps in seeing into a room that is dark. Also, it may be useful in the unlikely event that the takers try to escape into the dark. However, numerous lights in a suburban environment would lead to contrast degradation, limiting the value of LLLTV.

An IR sensor detects thermal contrast, allowing us to see body heat. Given that the outside air temperature is cool (45°F), an IR sensor detecting thermal contrast would be helpful. Although IR detectors cannot see through walls, the walls of rooms in use would likely be warmer that those not in use (Fig. 4). It is likely that all the hostages would be in one room so that they are more easily controlled. If a person were sitting with his back against an outside wall for an extended period of time (quite possible in a hostage situation), it may be clear from an IR image that one or more hostages were on the inside of that wall. It may also be possible to detect the thermal image of a gun in the hands of a taker, particularly if he were to step outside or appear through an open door or window. A rifle would show as a long dark shape contrasting with the brighter background of a warm body. For this mission, an IR sensor is the best compliment to an HD visual sensor.

Fig. 4: IR image of a house
(Image: www.labprohomeinspection.com)
Draganfly recommends the use of two sensors for the payload of the Draganflyer X6: the Panasonic DMC-ZS30 (Fig. 5) with a 14MP CMOS sensor for HD video and photos as well as a FLIR Thermal Imaging sensor (model not specified) with a 19 mm lens providing detailed real-time 324 x 256 thermal imaging.

Our sensors expert from Tactical Electronics also provided information regarding sensors used on the RAPTR helicopter:

**Question**: What EO/IR sensors would be best on the RAPTR platform for a hostage crisis situation?

**Answer**: For most tactical operations, I would recommend HD video and thermal video capability. We currently utilize a 26x zoom, image stabilized, Sony EO sensor and the FLIR Quark 640 thermal camera core for our LE gimbal (Fig. 5).

**Question**: What would be the cost for such a system?

**Answer**: The cost of a RAPTR system varies depending on the system and sensor package configuration. Cost can range from $70K to $150K, depending on selected options and capability, training and maintenance plans.

![Fig. 5: Panasonic DMC-ZS30 (left) and FLIR Quark 640 (right)](Photos: www.thenewcamera.com; www.oemcameras.com)

5. CONCLUSIONS
Our mission to provide intel during the hostage crisis is best accomplished by using the RAPTR UAV helicopter with HD video and thermal sensors. Given the limited scope of this paper, only two platforms were evaluated in detail. A great deal more research would need to be conducted to make a well informed decision as to the investment on a specific UAS for real-world hostage rescue needs. There is no doubt that unmanned systems will continue to provide LE with a powerful tool that provides a tremendous tactical advantage in situations such as the hostage crisis we considered here. The use of UASs will continue to develop and grow as the advantages of their implementation are realized and embraced.

**Acknowledgements**
The author would like to thank Tactical Electronics for sharing their expertise on the use of UAVs for law enforcement.

6. REFERENCES
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7. NOTATION

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<tr>
<th>Abbreviation</th>
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<tr>
<td>COA</td>
<td>Certificate of Authorization (from FAA)</td>
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<td>CONOPS</td>
<td>Concept of operations</td>
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<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<td>EO</td>
<td>Electro-optical</td>
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<td>FLIR</td>
<td>Forward looking infrared</td>
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<td>GCS</td>
<td>Ground control station</td>
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<td>HD</td>
<td>High definition</td>
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<td>IR</td>
<td>Infrared</td>
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<td>LLLTV</td>
<td>Low light level TV</td>
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<td>MAV</td>
<td>Micro air vehicle</td>
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<td>MAV</td>
<td>Micro air vehicle</td>
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<td>MTOW</td>
<td>Maximum takeoff weight</td>
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<td>RAPTR</td>
<td>Remote aerial platform/Tactical reconnaissance</td>
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<td>RSTA</td>
<td>Reconnaissance, surveillance, and target acquisition</td>
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<td>sUAS</td>
<td>Small unmanned aircraft systems</td>
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<td>sUAV</td>
<td>Small unmanned aerial vehicle</td>
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<td>UA</td>
<td>Unmanned aircraft</td>
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<td>Unmanned aircraft systems</td>
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<td>Unmanned aerial vehicle</td>
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