UNMANNED AERIAL VEHICLES - A CLEAR AND PRESENT DANGER, AND WHAT WE CAN DO ABOUT THEM

by **MAJ Jerry Chua**

Abstract:

In this essay, the author explores how Unmanned Aerial Vehicles (UAV) have been transformed from a simple daily equipment that everyone uses, to a deadly weapon that is utilised by both military and terrorists. According to the author, there is no single solution to deal with the threat of UAVs. Possible defence concepts such as geo-fencing, high energy lasers and jamming may still not succeed. These are single solutions where a full breach would occur once that one layer was broken. The author then proposes a multi-layered approach in dealing with UAVs to provide for contingencies in the event that one layer fails. This five layer defence model comprise the concepts of Prevention, Deterrence, Denial, Detection and destruction/Interruption. With this model, the author discusses how Singapore can prevent attacks from UAVs and plan a counterattack against the aggressor.

Keywords: Multi-Layered Approach; Resilience; Conventional Barricades; Continual Vigilance; Crisis Management

INTRODUCTION

You can hear them buzzing around in the parks. You can see them being used for unique vantage points in wedding videos. You can see them displayed in all shapes and sizes in your neighbour toy shops.

With improvements in technology leading to the widespread commercialisation and tumbling prices of UAVs, quad-copters and recreational drones are now a common sight. Corporations are also swiftly catching onto the potential avenue to reduce their overheads, with Amazon announcing the 'Amazon Prime Air', a home delivery service using UAVs.

However, increased usage of UAVs is not without its downside. With their agility, small size, and ability to circumvent traditional barricades, UAVs make for a good delivery platform for more malicious packages by terrorist groups and self-radicalised individuals. Recognising the danger posed by such groups, law enforcement and national defence agencies are scrambling for possible solutions. These have ranged from high tech jammers, space age Lasers and even the unconventional employment of trained bald eagles.[1] However, effectively dealing with such threats requires more than just new weaponry, but a more comprehensive, multi-layered approach.

A ROSE BY ANY OTHER NAME

Searching for the definition of Unmanned Aerial Vehicles yields a dazzling array of results, with some even including Cruise Missiles.[2] A cursory search of the articles on UAV threats throws out several nomenclatures such as Unmanned Aerial System

(UAS), drones, Remote Controlled Aircraft (RCA) and Remotely Piloted Vehicle (RPV) that are seemingly used interchangeably.

While the terms used differ, their meanings are fairly aligned, with the Merriam-Webster dictionary defining drones as 'an unmanned aircraft or ship guided by remote control or on board computers' and UAV as a RPV.[3] The Federal Aviation Administration defines a UAS as 'the unmanned aircraft and all of the associated support equipment, control station, data links, telemetry, communication and navigation equipment, etc., necessary to operate the unmanned aircraft' and includes hobby aircraft as part of the definition.[4]

Along with the non-standard nomenclature, there are also no industry standard classifications for UAVs. However, classes such as micro- and mini- are widely used. An example of the some of the classifications can be seen below in *Table 1*:

For the purposes of this essay, the nomenclature UAV will be used, as the focus is on the platform, rather than the supporting equipment. The UAVs described in the essay are assumed to be consumer grade and widely available, belonging to the micro- and mini- classifications.

With the increased awareness of UAV threats, several sensor platforms have been designed around the detection of UAV targets.

ATTACK OF THE 'DRONES'

Law enforcement agencies including the United States (US) Department of Homeland Security (DHS) and New York Police Department (NYPD) have issued assessments and warnings that micro- and mini-UAVs could be used as tools to mount terror attacks.[5] Despite their small size and limited endurance, these UAVs' small Radar Cross Section (RCS), agility and ability to circumvent the conventional barricades make them a deadly addition to the potential terrorist's arsenal. There are three potential scenarios that a UAV attack could pan out.

Scenario 1: Individual or terrorist group flies UAVs loaded with explosives with the objective of attacking a Key Installation (KINs) or Very Very Important Person (VVIP).

Though the weight that the UAV can carry is limited, it is able to carry the explosives closer to the target area, flying over the fences and walls. This allows it to cause more damage, potentially

Category	Weight (kg)	Altitude (ft)	Endurance (hr)	Range (km)
Micro	<1	300	1	<5
Mini	<25	<10,000	1-6	<25
Close Range	<200	<15,000	4-8	<75
Small Range	<750	<25,000	8-24	<200
MALE	>1,000	<30,000	>24	>1,000
MALE +	>3,000	>30,000	>24	>1,000
HALE	>3,000	>45,000	>24	>1,000

Table 1: Classification of UAVs by Range and Endurance.[6]

triggering off secondary explosions if the target was a petroleum-chemical or nuclear power plant. In the case of the VVIP, the UAV is able to fly over the protective bulletproof glass before detonating, causing serious injury or even death.

KINs such as the White House and French nuclear power plants have been overflown UAVs before, with the latter being overflown on no less than 13 occasions.[7] The latter scenario of an attack on a VVIP could have also played out during the party campaign event when a Parrot AR.Drone flew and crashed, metres from German Chancellor Angela Merkel.[8] While these cases mentioned were resolved peacefully, such gaps in security could have been exploited by individuals with sinister intents.

Figure 1: A Parrot AR.Drone, similar to the one that flew and crashed within metres of Germany Chancellor Angela Merkel during a Democratic Party campaign event.

Scenario 2: Individual or terrorist group flies UAV loaded with Chemical, Biological, Radiological or Explosive (CBRE) agents and releases/triggers it during a crowded event.

The direct causalities are few, but the resulting panic triggers a human stampede, causing mass causalities as people rush towards the exits. While there have been no documented cases of UAV attacks triggering human stampedes, there have been several

occurrences of such tragedies triggered by other reasons, notably during the Hajj in Mecca, Saudi Arabia.[9] With similar conditions of high crowd density and limited exit points, it will not be hard to imagine mass panic sweeping over the crowd following an explosion.

Scenario 3: Individual flies the UAV into the flight path of a commercial or military aircraft that is taking off or landing. The aircraft smashes into the UAV, causing injury to the pilot and damaging the aircraft, potentially causing the aircraft to crash.

As with scenario 2, there have been no documented cases of UAV strikes causing damage to an airborne aircraft. However, it was reported in the US Airspace alone, there were more than 300 cases of close proximity flights between a manned aircraft and UAV (classified as 'close encounters') between 13th December and 15th September.[10] Even without malicious intentions, the high occurrence rate of such potentially catastrophic incidents is a cause for concern.

With their agility, small size, and ability to circumvent traditional barricades, UAVs make for a good delivery platform for more malicious packages by terrorist groups and self-radicalised individuals.

CHALLENGES OF COUNTERING UAVS

Though it is generally acknowledged that UAVs pose a potential threat to security, dealing with them is not as intuitive. Due to their small RCS, low speed and flying altitude, UAVs are inherently difficult to detect and classify using conventional radar systems, as these radars were designed to filter out such plots as noise to avoid picking up birds and buildings by mistake.

Electro-Optical/Infrared (EO/IR) sensors will similarly experience problems with the picking up and tracking of such targets due to their small physical size. Additionally, the UAV's low altitude could cause its image to be blurred by the heat radiating off the top of buildings.

Even if the detection hurdle was crossed, most air defence systems, being designed for engaging conventional air threats such as combat aircraft, precision guided munitions and bombs on a large scale, are ill equipped to handle UAVs.[11] The resulting collateral damage caused by the firing of such weapons in fact, can be more than the UAV and the resulting panic can trigger off a human stampede or crush, indirectly accomplishing the intent of the attack.[12]

UAVs are also able to circumvent or fly over the most commonly used barriers such as fences, concertina wires and walls, making their point of entry unpredictable. This, coupled with their agility, means that UAVs will likely be the pop-up targets, reducing the reaction time for the authorities.

SINGAPORE IN CONTEXT

Singapore is not new to the threat of terrorism, with the terrorist group Jemaah Islamiyah (JI) revealed to have planned to attack foreign and local targets in Singapore as early as 1997.[13]

Singapore is a known target for ISIS and its supporters. In 2015, two Singaporeans were also detained under the ISA with the intention to join ISIS.[14] Singapore also resides in a volatile region, with suspected ISIS militants and supporters found in both Malaysia and Indonesia.

However, Singapore presents several other unique characteristics that makes her particularly susceptible to a UAV attack.

Firstly, with a population density of 7,736

per square kilometre, Singapore is one of the most densely populated countries in the world.[15] With our relatively small land area, our critical infrastructure and airfields are also closely located with the general populace. In particular, the flight paths of most our civilian and military aircraft either take them above populated areas, or are clearly visible to the public eye. The island is also completely urbanised, with most parts covered with high-rise buildings and estates.

With few regulations governing the sales of UAVs, these are widely available in all the toy and hobby stores in Singapore.

Putting these factors together, Singapore is a highly attractive target for UAV attacks, with a high payoff arising from the dense population and her status as one of the most secured and prosperous countries in the region. Additionally, there are readily available sources of acquiring and training on UAVs, and any planned attack will be hard to detect until the very last minute.

SINGAPORE'S MODEL FOR DEFENCE

Effectively dealing with the UAV threat requires a whole-of-government approach. In the qualitative study *'Examining Unmanned Aerial System Threats and Defences: A Conceptual Analysis'* conducted by Ryan J. Wallace and Jon M. Loffi, it was highlighted that none of the defence concepts proposed thus far were complete models. Instead, they were merely focused on single solutions where would cause a full breach in defences once that one layer was broken.[16] Consolidating and organising the various defence concepts, they developed a five layer defence in depth model (Prevention-Deterrence-Denial-Detection-Destruction/Interruption).[17] Drawing inspiration from their model, the following model for Singapore's defence against UAVs is
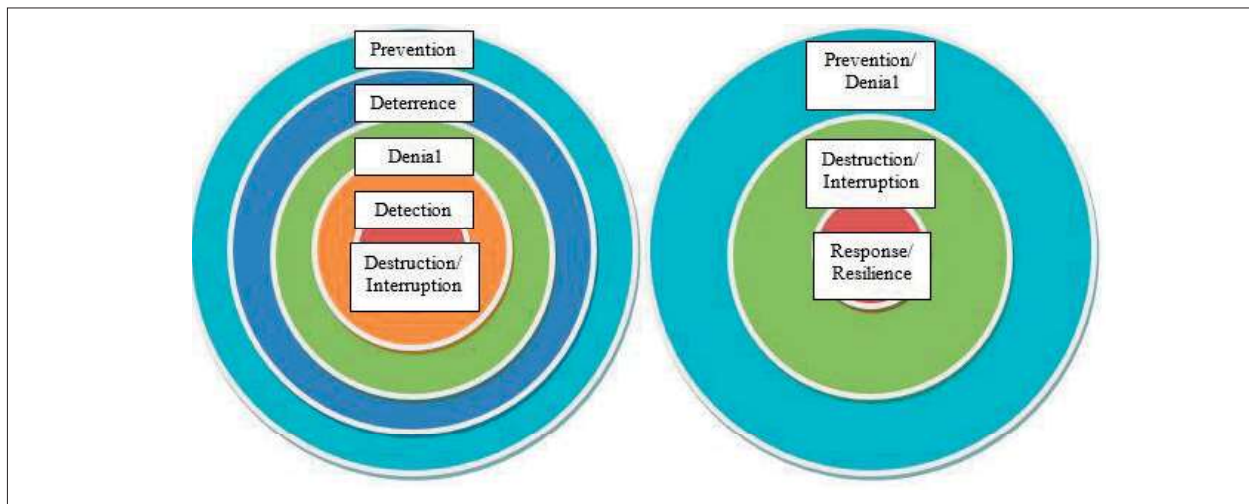
Figure 2: UAS Defence in Depth Model by Ryan Wallace, et al. (left), Proposed Model for Singapore's Defence against UAVs (right).[18]

proposed.

The outermost concentric circle of Prevention/ Denial merges encompasses all actions taken to prevent such attacks from occurring. The second circle includes all the actions to prevent such attacks from succeeding and the innermost circle describes the post-attack actions.

By putting in place and regularly practising crisis management procedures in the event of a successful terrorist attack, the various agencies will be able to respond swiftly and decisively, limiting public disruption and alarm, while bolstering confidence in the authority's ability to handle such situations.

PREVENTION/DENIAL

On the forefront of the efforts to prevent UAV attacks on Singapore soil is the continual vigilance from intelligence agencies such as the Internal Security Department (ISD), and Intelligence Departments from the Military and Police. Intelligence efforts in

worldwide have been instrumental in the uncovering of plans by self-racialised individuals and terrorist groups to perform attacks using UAVs. Notable examples include (1) Rezwan Ferdaus, who plotted to carry out attacks on key US installations using remote-controlled models of the F-86 Sabre packed with explosives, (2) Al-Qaeda plot to release chemical agents in Iraq using remote-controlled helicopters, and (3) Islamic terror plot to employ UAVs (packed with explosives) as guided missiles for a planned assassination in Germany.[19]

Complementing intelligence efforts are legislative Acts that will control the flying activities of the UAVs. This includes both the enactment of the laws, and its enforcement. On the former, Singapore has taken the first step by passing the Unmanned Aircraft (Public Safety and Security) Act 2015, which amends existing Air Navigation, and Public Order Acts.[20] This act restricts the operations of UAVs in terms of UAV weight, operating height and activities, and lays down the situations where a permit must be obtained. While the Act's enactment is clearly a step in the right direction, its enforcement presents two inherent difficulties. Firstly, most mini- and micro-UAVs remain widely accessible to the public without

purchase controls. This presents opportunities for individuals to purchase and perform modifications to enhance its performance for malicious purposes. Secondly, encounters with the UAV tend to be fleeting, reducing the amount of time for authorities to detect and detain the perpetrators. Educating the public is one possible solution to mitigate the issue of enforcement. Similar to the wide-spread campaign educating the public to report suspicious bags, a campaign educating the public to report suspicious UAV flying activity could provide the authorities with 'extra pairs of eyes', and improve responsiveness.

Another potential solution is to enforce the hard-coding of navigation algorithm by the UAV manufacturers. Referred to as 'geo-fencing', this would allow the authorities to establish vital fences around the KINs, preventing the UAVs from overflying pre-set boundaries. [21]

DESTRUCTION/INTERRUPTION

Should deterrence and denial fail, and an attack is carried out, the next step is to prevent the attack from succeeding through destruction (hard kill) or interruption (soft kill).

To accomplish this, however, requires overcoming the detection hurdle. For this, the SAF could leverage on the expertise within the Air Force and Army in the sourcing and employment of sensors. With the increased awareness of UAV threats, several sensor platforms have been designed around the detection of UAV targets. One such platform is the Giraffe Agile Multi-Beam (AMB) produced by SAAB, which is allegedly able to distinguish UAVs from ground and sea clutter using its Enhanced Low, Slow and Small function.[22] While destruction could be most conveniently carried out using kinetic weapons such as firearms and Ground Based Air Defence (GBAD) assets, the resulting collateral damage and panic caused could outweigh the damage caused by the UAV itself. Additionally, due to the pop-up nature of the targets, the engagement window could be very small.

With their speed of light and projectile-less engagements, coupled with pinpoint accuracy, High Energy Lasers (HELs) could offer a potential answer. Once the subject of scepticism from US President Ronald Reagan's Strategic Defence Initiative (nicknamed 'Star Wars'), advancements in technology and defence demands have since propelled the

Figure 3: 'See Anything Suspicious' posters used by the British Transport Police to raise awareness about suspicious packages.[23]

Figure 4: LaWS is the first operationally deployed HEL weapon and is installed aboard the USS Ponce.

development of HELs, with the first operational deployment of a HEL weapon, LaWS (Laser Weapon System) on board the *USS Ponce* on 14th September.[24] The incorporation of such weapons could provide the SAF with the capability to engage and take out UAVs while minimising collateral damage.

As UAVs are controlled using radio frequencies, commonly the 2.4 GHz for the newer models and 72 MHz and for the older ones, jamming the UAV's signal could also prevent it from completing its attack.[25] Once a UAV is interrupted due to jamming, the UAV would either hover, descend to land, or return to its point of origin.[26] Battelle, a non-profit Research and Development (R&D) organisation from Ohio, has developed one such short range jammer designed against UAVs. Dubbed the *DroneDefender*, the directional jammer can allegedly jam UAV signals

at up to 400 metres away and represents a potential soft kill option for law-enforcement officers guarding KINs or patrolling major events.[27]

Effectively dealing with the UAV threat requires a whole-of-government approach.

RESPONSE/RESILIENCE

While the actions pre- and during UAV attacks are critical, the post-attack actions are no less important. There may be situations where attacks have been successfully carried out and the authorities will need to take action in the aftermath to prevent future attacks from occurring. This is because terrorism's goal does not lay in the execution of the attack, but the disruption to normal life and publicity that it generates in the aftermath.[28] The key to preventing

such future attacks hence lies in the swift response of the authorities and resilience of the populace.[29]

By putting in place and regularly practising crisis management procedures in the event of a successful terrorist attack, the various agencies will be able to respond swiftly and decisively, limiting public disruption and alarm, while bolstering confidence in the authority's ability to handle such situations. In Singapore's context, Exercise Northstar serves as a good platform to practise inter-agency co-ordination and collaboration. These series of exercises have typically been modelled after successful terrorism attack and could be expanded to deal with the sightings of UAVs and human crushes.

On building resilience, the public can be educated about what they can do in the event of a terrorist attack. This allows them to play an active role rather than remain as passive observers in the aftermath. The public should also be given an accurate assessment of the possibility of a successful terrorist attack rather than fear-mongering or overly rosy messages. Over the years, Singapore has witnessed a gradual shift in the messaging from the leadership that terrorism is something that we will need to be mentally prepared for.[30]

Brian Jenkins on the RAND blog sums up the inner-most circle or Response/Resilience with, "We may have to live with terrorism, but we do not have to live in terror."[31]

CONCLUSION

When dealing with the UAV threat, there is no single 'magic bullet' or permanent solution. Geo-fencing could give way to hacking, HELs suffer from attenuation during adverse weather, jamming requires precise knowledge of the frequency band used, and building resilience takes time. Hence, it is critical for

a multi-layered approach to provide for contingencies in the event that one layer fails.

One thing is clear: the proliferation of the UAVs is here to stay, and its payloads and endurance could only increase with the advancements in technology. In the fight against the malicious use of UAVs, the potential aggressors already have the tools at hand.

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