The Role of Drones in Future Terrorist Attacks

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Preface

The growth in commercial and personal drone usage has driven rapid developments in drone capabilities. Commercially-driven improvements have included increased range, speed, payload capacity, new control and coordination methods and locomotion manner. As with most dual-use technologies, terrorists have adopted drones to conduct standoff attacks against a variety of targets. Similarly, efforts to counter drones are also developing and improving. However, these efforts are hindered by the need to limit undesired impacts, by a large and diverse physical environment and by rapid advances in drone technology. Countering and defeating terrorists' drones is already problematic; it will only become more difficult with increased legal use and improved capabilities of drones across the board.

The Role of Drones in Future Terrorist Attacks

Introduction

The technology of today, while impressive, is developing the tactics and techniques of future terrorist attacks. The most prescient current technology that will enable future terrorist attacks is the drone. Drones have the ability of providing standoff, which can enable terrorists to conduct multiple attacks nearly simultaneously, rapidly magnifying their overall effect. A terrorist attack is meant to create an atmosphere of fear to influence a target audience—a civilian population or government—to force or impose political change. The massive increase in the number of form factors, capabilities, ease of access and ease of operation of drones at low cost will make them the weapon of choice for future terrorists.

The majority of past terrorist attacks have relied on weapons and materials that were readily available. In the United States, the perpetrators of the most significant attacks in the past 30 years, the Oklahoma City bombing[1] and the 9/11 attacks,[2] purchased the majority of their required materials legally. In addition to acquiring materials, terrorist groups need individuals to carry out their attacks. Many groups typically conduct attacks with the expectation that their members will sacrifice themselves during the attack, either by being caught or killed. The use of drones, however, can allow an individual or a small group to conduct multiple attacks without self-sacrifice.

Past Development and Adaptation of Drones

Professional militaries have used large, unmanned, aerial vehicles to support combat operations since World War II. Their limited initial success as weapon systems during World War II had expanded into intelligence collection by the time of the Korean War.[3] As with other military

For the purposes of this paper, the term “drone” is used to describe any system that is remote- or computer-controlled, that provides its means of locomotion by built-in systems and that is not built for the specific purpose of military application. The definition includes systems that move in the air, on the ground, on the surface of water and underwater.

technologies, over time, the capabilities of the systems found commercial applications. Beginning in the early 2000s, the use of airborne drones by private individuals began to increase rapidly, caused primarily by higher energy capacity of drone batteries, reduced motor size and enhanced motor power output. These factors enabled a much smaller form factor, with many drones being less than 2 ft (0.6 m) across, which allowed them to be produced commercially at a significantly reduced cost.

Between 1994 and 2018, more than 14 planned or attempted terrorist attacks took place using aerial drones. Some of these were:

- in 1994, Aum Shinrikyo attempted to use a remote-controlled helicopter to spray sarin gas, but tests failed as the helicopter crashed;[4]
- in 2013, a planned attack by Al-Qaeda in Pakistan using multiple drones was stopped by local law enforcement;[5]
- in 2014, the Islamic State began using commercial off-the-shelf and homemade aerial drones at scale during military operations in Iraq and Syria;[6]
- in August 2018, two GPS–guided drones, laden with explosives, were used in a failed attempt to assassinate Venezuelan President Maduro;[7] and,
- in January 2018, a swarm of 13 homemade aerial drones attacked two Russian military bases in Syria.[8]

Terrorist groups have used or attempted to use aerial drones to conduct many different types of operations, including intelligence collection, explosive delivery (either by dropping explosives like a bomb, the vehicle operating as the impactor, or the drone having an equipped rocket-launching system of some type) and chemical weapon delivery.[9] Once Pandora's box was open, bad actors adapted quickly and began using drones to plan and conduct attacks.

The number of nonstate actors currently using aerial drones has increased each year. Currently, there are multiple groups operating in Africa, the Middle East, the Arabian Peninsula, Southeast Asia, Eastern Europe and South America.[10]

Current and Future Advances

The rapid popularization of drones for average consumers and businesses has created a market that will continue to drive the technological improvement of drones for the foreseeable future. Improvements will extend to sizes, form factors, energy storage, techniques for propulsion, sensors and the ability to utilize and integrate advanced computer capabilities. Collectively, these improvements will increase the range, lifting capacity and overall capabilities of drones, making them both more lethal and more difficult to counter.

Current commercial uses for aerial drones include inspection of roofs with thermal cameras, surveying large areas (such as agricultural fields, or acting in response to disasters), chemical application on agricultural fields, product delivery, photography, videography and drone racing, to name a few. Noncommercial uses can include all of the above, as well as personal use by hobbyists. Not surprisingly, each of these uses can be modified to support terrorist actions.

Initial production models of what would become modern drones were expensive, radio-controlled, gasoline-operated, small-model, fixed-wing airplanes and helicopters. As noted above, the increase in energy-dense batteries and high-efficiency electric motors, combined with the decrease in the weight and size of necessary electronics, began the modern quadcopter "boom." These small forms, less than 2 ft (0.6 m) across, with limited lift capability, soon led to the development of eight-engine copters, capable of lifting 500 lb (227 kg) at a speed over 80 mph (129 kph) and a range of 10 mi (16 km).[11] Gas-powered jet engines are being designed and produced for small drones, with some models able to operate and land on water. These jet engines provide speeds over 600 mph (965 kph) and altitudes up to 30,000 ft (9,144 m).[12]

Speed is not limited to large drones, though; drone-racing leagues have been created with small aerial drones reaching 80 mph (129 kph) for 3- to 5-minute flight times. Control of these high-speed drones is maintained by pilot use of video goggles to utilize a first-person view from the drone itself.[13] Increased battery energy density has also enabled the creation of microdrones, small enough that they can fit in the palm of someone's hand. Some models are equipped with optical cameras and are capable of ranging hundreds of yards or meters at speeds up to 15 mph (24 kph), either autonomously or under pilot control—all for less than 200 U.S. dollars (USD).[14]

In 2020, the Federal Aviation Administration (FAA) approved the commercial use of drones beyond the pilot's line of sight.[15] Lifting this restriction, combined with the introduction of regular commercial drone flights in the continental United States, will make countering weaponized drones significantly harder.

In addition to improvement in aerial drones, hobbyists and companies are developing drones that can operate in more than one environment. Some drones are now capable of moving from a wheeled system to an airborne system. Other drones are capable of moving from subsurface (underwater) to airborne modality.[16] The range of direct control has historically limited waterborne drones; however, advances in automation and computer capabilities have prompted a recent rise in their capabilities.[17]

Drone movement techniques are advancing. For example, some drones can now imitate animal movements, with several companies using biomimicry in their technology. Biomimicry has progressed to the point where some drones can operate in and around wild animals without disturbing them, moving in the water, air and on the ground with natural motions.[18] There are platforms that mimic the flapping of bird wings[19] and the swimming motion of fish.[20] Researchers have also begun experiments with synthetic feathers as control surfaces. The feathered wings provide greater efficiency of control, as well as being lighter than standard carbon and fiberglass control surfaces. These two improvements, together with power sources becoming more efficient, allow airborne drones to operate in higher winds and to provide longer airborne flight times.[21] Overall, these improvements have increased flight-time capacity from just a few minutes up to almost 30 minutes for some drone models, providing a significant gain in their overall range and carrying capacity.

Improvements in form factor and energy storage, critical to increasing the utility of modern drones, can lead to increases in the ease and range of control or to fully automated flight. Many early-model drones were difficult to control; they operated on simple one-way radio control from pilot to drone, which meant they required a direct line of sight. Now, many modern drones operate within the 2.4- to 5-GHz radio frequency (RF) band, which allows for direct control of the drone at greater range. This increased RF bandwidth also enables the drone to send information back to the pilot. The majority of modern drones use this ability to transmit a live video feed to the pilot—meaning that the drone can travel beyond the pilot's line of sight while still being controlled. Consequently, some models are able to reach altitudes of 1,500 ft (457 m) and flight ranges out to 5 mi (8 km).[22]

The quality of computer-aided piloting software in modern drones has improved dramatically, with many platforms having self-correcting, full-autopilot and visual functions that can track a person or object. This autopilot functionality includes the ability to plot flight paths that the drone can execute independently from direct pilot control.[23] Many drones equipped with such functions allow the pilot to program autonomous flight paths to distant locations via a simple graphical user interface. Automated functions also include the ability to return to a pre-programmed point if a loss of signal occurs. Several companies have created drones that are fully autonomous and utilize forms of object recognition, enabling the drone to autopilot while tracking and following a person or object in real-time—and while flying with automated obstacle avoidance through complex environments.[24]

In addition to improved capabilities, in-flight automation and visual object recognition capability, optical and sensor capabilities have also improved rapidly and dramatically. The capability of drone sensors is crucial for increasing their functionality and allows for the use of facial-recognition technologies. Optical sensors can now visualize and transmit video at 4K resolution, including infrared and night vision.[25] Improvements in the optics carried by drones have also enabled an increase in the zoom range, with some systems having zooms up to 30x.[26] Combined with improvements in facial and object recognition, these sensors enable drones to target and track a person or object from a significant distance.

One of the most recent developments in drone technology is the ability to coordinate multiple drones simultaneously. These so-called "swarms" can overwhelm defensive capabilities. In 2018, a drone swarm attacked a pair of Russian bases in Syria. In the attack, 13 fixed-wing drones attempted to deliver aerial bombs from a distance of more than 31 mi (50 km).[27] These homemade drones were fairly low-tech when compared with commercial off-the-shelf systems. Even homemade drones will begin to see improvements in onboard technology, as there exist forums and websites dedicated to the sale of drone parts, allowing individuals to build custom drones. One technology that could enable drone swarm efficiency is ad-hoc Bluetooth networks. These Bluetooth networks are low-power, local networks that self-organize and share information in real-time.[28] The ability of swarms to self-organize and self-coordinate will continue to improve with computing power, which is simultaneously improving the ability of drones to autopilot.

It is worth noting that the rapid acceleration of drone technology is being driven by the expected quadrupling of global drone sales to 43 billion USD by 2024, up from 14.1 billion USD in 2018.[29]

Detection Systems

Both militaries and industry have recognized the weaponization of commercial drones. This recognition has driven the development of systems for detection and countering. In the United States, the FAA has recognized that drones are becoming more ubiquitous for corporate and personal use—and that there currently exists no system for tracking and deconflicting airborne platforms.[30] It has even proposed rules that would require drones over a certain weight to be equipped with a radio transponder to enable tracking.[31] Unfortunately, as with most trackers, these systems are easily disabled.

Detecting airborne drones is critical for interdiction. Such work largely falls within four categories: RF analysis, acoustic sensors, optical sensors and radar. RF analysis monitors the RF spectrum and detects the signals by which drones are controlled. RF analysis systems are incapable of detecting drones that are preprogrammed or that operate fully autonomously. Detection also becomes much more difficult in high-population areas, as the spectrum becomes noisier and more congested.[32] Next, acoustic sensors can be either one or multiple microphones that listen for the sound of the drone's high-speed motors or the blades of the drone moving through the air.[33] They are limited in noisy environments and have a range under 1,640 ft (500 m).[34] A drone traveling at 80 mph (129 kph) would cover 328 ft (100 m) in just under 3 seconds, or, at 15 mph (24 kph), in just under 15 seconds. Third, optical detection is the use of video cameras and computer algorithms to detect a drone. These systems are subject to high rates of false alarm and limitations in low light or with weather interference.[35] Finally, radar is the primary means of long-range detection. Long-range detection of drones can occur at up to 1.9 mi (3 km) and within line of sight. Radar is capable of detecting low-flying and small drones, although difficulties are encountered in high-clutter environments.[36] Most radar systems are incapable of differentiating between a bird and a small drone.[37] Advanced millimeter-wave radar systems, however, can make this distinction by detecting the spin of the drone's rotor blades. Acoustic and radar detection will become more difficult with the increased use of biomimicry and synthetic feather flying systems, which will minimize noise and remove hard surfaces and blade rotation that are detectable by radar.[38]

Research into the detection of underwater drones is largely based on listening for changes in the ocean's background noise. Researchers believe that a passing drone will cause significant changes in sea-life activity, changing noise levels. Implementation of these systems would require placing arrays of hydrophones. As with the detection of airborne drones by acoustics, detection by hydrophones would be hindered by noisy environments, such as busy ports and waterways.[39]

Improvements in biomimicry, autopilot and ever-smaller form factors will continue to challenge detection systems. Combining these improvements with increases in speed and range places the advantage for bypassing detection systems with the drone operator.

Defeat Systems and Countermeasures

There are several drone countermeasures and active defeat systems. The first layer of defeat for most commercially-purchased systems is built-in software limitations, such as geofencing for GPS-enabled drones. With geofencing, limits are placed on GPS-enabled drones to prevent entering or use within restricted areas. However, a geofence database is managed by the company that built the drone, so it is often limited to critical facilities and military bases. Geofencing is simple to bypass, either by the owner not upgrading firmware or by attackers hacking the device.[40] Wrapping aluminum foil around the onboard GPS antenna can actually make geofencing ineffective, but it also limits piloting options for most drones.[41]

During RF jamming, communication between the drone and the pilot or GPS is disrupted. RF-jamming systems range in size and portability, from rifle-size jammers to those mounted on vehicles or buildings. These systems transmit a radio signal that overwhelms the GPS signal or the operator's transmitter. Interrupting this signal causes many drones to act under a lost signal response and either land, or, if enabled, return to a preprogrammed location. RF-jamming systems vary significantly in range and effectiveness. Most electronic rifle-style systems require line of sight; they also require the operator to keep the "rifle" aimed at the drone while disrupting the signal.[42] Larger vehicles and building systems are capable of omnidirectional jamming. The technique of RF jamming has shown overall mixed results when targeting and stopping unknown drone platforms. These mixed results are based on the fact that each commercial company builds its drones to its own specifications, and the end-user can further customize the system, including choosing which radio frequency it uses.[43] This individuality makes countering largely specific to each drone. Another risk for using large systems is that their broad overall output interferes with all other systems that use the 2.4- to 5-GHz and GPS signals for operations. In urban areas, RF jamming can impact home security systems, Wi-Fi networks, car locks and GPS navigation. Additionally, technology to counter RF jamming is already commercially viable; for example, Amazon has filed for patents to protect its proposed drone delivery fleet from RF jamming.[44]

Moving beyond RF jamming to physical countermeasures, the majority of options come in the form of a net. Nets are more advantageous than a physical impactor or birdshot, as they create a larger contact area against a moving target and are thus more likely to entangle and disable an aerial drone's rotating blades. Net guns range in size from a handheld flashlight-shaped device, which shoots a 10 by 10 ft (3 by 3-m) net with a range of 49 ft (15 m),[45] to a shoulder-fired net bazooka, with a range between 328 and 820 ft (100 and 250 m).[46] In addition to these purpose-built systems, specialty shotgun ammunition has been designed that shoots a 5-in (13-cm) net out to 164 ft (50 m).[47]

Birds of prey were utilized for a short time as a natural kinetic impactor, but, due to their limited operational hours, territorial natures and many other complicating factors, they have largely been retired from drone countermeasure operations.[48] Their weakness may be mitigated by the use of flocking birds. For example, pigeons are being conditioned to be attracted to the sounds and motions of aerial drones and may soon be useful in some countermeasures.[49] Similarly, marine mammals have been used by the United States Navy since the 1960s to identify mines, retrieve equipment and identify intruders.[50] These marine mammals may be capable of interdicting underwater drones, though limitations similar to those experienced with birds would likely exist.

Ultimately, RF jamming has a limited effective distance, and unintended interference makes the use of RF jamming ineffective for continuous countermeasures across large areas. A majority of commercial off-the-shelf drones are capable of flying at altitudes up to 1,500 ft (457 m) at speed, making kinetic targeting difficult, if not impossible. Achieving this physical separation provides an advantage to the drone operator, in that most counter systems' identified maximum range is under 656 ft (200 m).[51] The use of animals for countering drones has potential, but further research and training is required.

Additional Considerations

Cost is a factor in planning and executing terrorist attacks. The cost of the 1995 Oklahoma City bombing was approximately 5,000 USD[52] (inflation-adjusted to 8,582 USD in 2020),[53] while the cost of the 9/11 attacks was between 400,000 and 500,000 USD[54] (inflation-adjusted to between 590,000 and 738,000 USD in 2020).[55] The estimated cost for the attacks in Mumbai, India, from 26–29 November 2008, was under 150,000 USD.[56] These figures show the broad financial range and capacity within which terrorists are capable of operating to conduct attacks. The price range for aerial drones varies from 20 to more than 20,000 USD, while the price range of most commercial off-the-shelf drones that are capable of lifting a weapon-sized payload is between 1,000 and 2,000 USD. The cost of most underwater drones is between 1,000 and 4,500 USD.[57]

While commercial purchase is an option, many hobbyists and terrorist groups have taken to constructing purpose-built aerial drones. Louisiana State University published an open-source article on building a homemade, GPS-guided, radio-controlled aerial drone that would be capable of carrying 10 lb (4.5 kg) of material for 10 minutes—with no specialty equipment required and using an open-source software—for under 2,000 USD.[58] Instructions exist online for how to 3D-print micro- and small drone bodies, only requiring the purchase of the motors and computer components.[59] The ease of acquisition and production makes these systems ideal for low-cost attacks. The open-source software allows for other rapid capability additions that could remove the need for guidance by GPS or radio control by enabling some other form of control, e.g., inertial, terrain-following or beacon-based.

Conclusion

Terrorist groups have already begun to use aerial drones to conduct and coordinate attacks. As these groups learn lessons from previous attacks, most notably the Islamic State's use of drones during military operations in Mosul, they will continue to adapt. The rapid improvements in drone technology and its increasing capabilities will provide terrorist groups with multiple new avenues to sow fear.

A particularly frightening application of drones is the distribution of chemical and biological agents, especially infectious diseases. Conversations around infectious disease are so prevalent, and the fear is known. Terrorists do not even have to use an actual biological or chemical weapon to perpetrate the attack. The simple act of spraying water or some other household cleaning agent over a crowded area would be enough to create panic. Critical infrastructure is also vulnerable, and hardening thousands of locations against attack would be financially restrictive, at best. Probable infrastructure targets include fuel or water storage facilities, gas pipelines, power distribution plants and food supply locations, many of which are minimally or completely unmanned. In 2013, a targeted attack against a power distribution facility in California almost sent a significant portion of the state into darkness. The attack against this unmanned facility caused 15 million USD in damages. Because of the low production quantity of damaged specialty equipment, it took weeks to repair the damaged facility and return operations to normal.[60] Had the perpetrator attacked more than one facility, the disruptions and damage would have been extensive.

The ability of a small group or individual to conduct multiple simultaneous attacks, at a relatively low cost and with significant standoff distance, will lead to the use of drones as a primary tactic of future terrorist attacks. The advantage is with the attacker; expensive counter systems for drones can be defeated with the addition or removal of specific onboard systems or a change in modality. Terrorists have already begun to experiment with the use of drones in their attacks—it would only take one high-profile attack for all terrorist groups to realize and exploit this technology.

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