**Title page**

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**Title:** Consumer drone evolutions: Trends, spaces, temporalities, threats

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**Title:** Consumer drone evolutions: Trends, spaces, temporalities, threats

**Abstract:** While the drone has become synonymous with the War on Terror, the asymmetric iconography of the battlefield is shifting. Commercially available off-the-shelf (COTS) drones are increasingly prevalent features of global battlefields, employed by non-state actors in both visualizing such spaces, and the directing and inflicting of harm therein. As such usage increases, so too do concerns around the evolving adoption and adaptation of these devices, and their potential portability into homeland spheres. While cognizant of the range of positive drone applications, it is asserted that such platforms nonetheless remain simultaneously bound to an inverse potential for exploitation. With the aim of examining drone risk, this article approaches the consumer drone through a series of sites and spaces through which it is both technically and socially constructed. Reflecting upon industry innovation, community-driven experimentation, and evolving airspace – the article ultimately calls for greater attention to the drone’s malleability, arguing that understandings of the COTS drone must remain attentive to both drone potential and potential drone threat.

**Keywords:** Drones; Unmanned Aerial Vehicles; Risk; Threat; Technology; Innovation; Mitigation; Airspace

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**Consumer drone evolutions: Trends, spaces, temporalities, threats**

**Introduction**

*“The past decade has witnessed an explosion in the popularity, availability, variety, and capability of small, remotely-piloted aerial vehicles*”[[1]](#endnote-1)

The Unmanned Aerial Vehicle, or drone as it more popularly known, has become synonymous with the War on Terror, often dubbed the iconic platform of the ongoing conflict. While surrounding debate has typically focused upon large platforms utilized extensively by the US Air Force and Central Intelligence Agency (CIA), the asymmetric iconography of the War on Terror is shifting. Commercially available off-the-shelf (COTS) drones are becoming an increasingly prevalent feature of the battlefield, employed by non-state actors in both the visualizing of such spaces, and the directing and inflicting of harm therein. As the use of such platforms increases, concerns have grown around both the evolving adoption and adaptation of these devices, as well as the potential *portability* of malicious non-state actor drone use into non-battlefield domestic spheres.[[2]](#endnote-2)

Drones are, after all, increasingly present, trialed, and under development for applications in domestic airspace. Here, drones are both deployed and anticipated in roles ranging from inspection and infrastructure monitoring, security provision, emergency assistance, image capture and videography, to the delivery of commercial and medical goods.[[3]](#endnote-3) Just as the contexts and applications with which drones are associated are multiple, so too are the platforms themselves. Spanning rotary and fixed wing designs,[[4]](#endnote-4) and the development of both commercial proprietary platforms (such as Amazon’s Prime Air delivery drone) and COTS devices sold to both commercial and consumer markets, a growing ecosystem of drones has emerged. Given both the scale and variety of platforms encompassed therein, this article centers its analysis upon consumer drones, namely those most commonly available and affordable for, marketed to and purchased by, everyday consumers. While cognizant that leaders of the consumer market, such as Chinese-manufacturer DJI, produce multi-application platforms marketed as both recreational or leisure and commercial-grade devices, what is shared in this space are evolving capabilities and imaginations surrounding the COTS drone. While acknowledging the range of positive and beneficial drone applications, the consumer drone, as this article asserts, nonetheless remains simultaneously bound to, and entangled with, an *inverse potential for exploitation*. This potential became particularly salient when, on 4th August 2018, a high-end COTS drone was flown towards Venezuelan President Nicolás Maduro as he delivered a speech at a military parade. Capturing global headlines, the C4-laden, remotely-triggered, drone exploded in mid-air, marking an incident reported as an assassination attempt.[[5]](#endnote-5) A second drone then detonated, crashing into a nearby apartment building. The platforms in question were reported as market leader DJI’s M600 model, a COTS platform costing $5,000 and purportedly able to carry 13lbs over a 3 mile radius. As this article unpacks, this case is indicative of a wider and emergent culture of malicious COTS drone deployment, repurposing and retrofitting devices with the intention of causing of harm and disruption.

In interrogating (potential) risks accompanying the COTS consumer drone, the article proceeds as follows. It first provides a brief overview of the evolving ways in which non-state actors have thus far deployed COTS drones, both in “tactical settings” on the battlefield,[[6]](#endnote-6) and in a variety of forms in the homeland. This overview acts as a contextual precursor for the article’s focus, namely an examination of (potential) consumer drone risks as approached through the lens of a series of sites and spaces through which the drone is both technically and socially constructed. The choice of wording here is intentional, responding to Klauser and Pedrozo’s call for greater attentiveness to the ‘making of’ the drone, that is the both the multiple “networks” and “domains of expertise” that underpin its design and deployment. [[7]](#endnote-7) In pursuit of this agenda, the article follows a tripartite structure, tracing (potential) and evolving drone risk in three key areas: *developmental trends, spaces*, and *temporalities*. In profiling first *developmental trends*, the article turns to industry innovations in the areas of intelligent flight and drone sociality, highlighting changing movements of the drone, and the ways in which these are supported, extended, and amplified online. The article then turns to explore emergent *developmental spaces* in which drone capabilities and applications are being stretched, re-imagined, and re-configured, driven instead by user and community ingenuity. Engaging with the emergent, yet increasingly popular space of ‘do it yourself’ (DIY) droning, the article highlights the importance of examining user-borne drone experimentation, or as drone researcher Don Rassler aptly describes it ‘improvised innovation’.[[8]](#endnote-8) The article then turns to *developmental temporalities*. Beginning with the assertion that it remains important to approach the drone at different points within its life-cycle, it turns from the supply chain, a preceding temporality which enables and facilitates non-state actor drone use[[9]](#endnote-9), to future-oriented projections, forecasts and anticipations which surround and fuel the drone’s future. Here, both the inherent tension that surrounds the drone as simultaneously operational asset *and* threat, and evolving risk within the context of evolving airspace itself, are considered. An overview of existing methods and modes of drone mitigation is lastly provided, with the aim of highlighting the complexity of the defense against the malleable and evolving errant drone. In approaching the consumer drone across distinct sites through which it comes to function, this article offers a discussion of drone risk attuned to the role of both capability and community, innovation and experimentation. In so doing, it highlights the drone’s malleability as a key consideration – demonstrating the drone’s multiplicity and slipperiness as a “heavy object, full of undiagnosed complications”,[[10]](#endnote-10) and the challenges of threat discernment and governance that accompany this status.

**COTS drone deployments**

Over the first decade of the War on Terror, military drones as both surveillance and strike platforms have become “central to US national security strategy”, as well as emerging as counterterrorism tools of choice for a growing number of nations.[[11]](#endnote-11) While most commonly considered as MQ-1 Predators and MQ-9 Reapers, military drone fleets are in fact increasingly varying in “size, shape, and sophistication”,[[12]](#endnote-12) constituting what can be understood as a vast ecosystem. Larger platforms piloted at considerable distance are, after all, increasingly coupled with smaller drones deployed by ground personnel – from the British Army’s Black Hornet, to the US Army’s deployment of COTS DJI drones.[[13]](#endnote-13) [[14]](#footnote-1) Collectively, the deployment of this suite of drones has sought to enable technological advantage over non-state actor adversaries. In seeking to disrupt the asymmetrical relations of the battlefield, non-state actors are, however, increasingly deploying COTS drones in both surveillance and improvised weaponized capacities.[[15]](#footnote-2) Groups of non-state actors including (but not limited to): the Islamic State (IS), Hezbollah, Hamas, and al-Qaeda have begun to employ COTS drones on the battlefield, deploying such devices with increasing frequency and an expanding spatiality[[16]](#endnote-14). As security scholar Ash Rossiter elucidates in a valuable overview of tactical battlefield applications, drones have been used by such groups in the: gathering of surveillance imagery, the direction of attacks, in weaponized capacities to conduct attacks, to overwhelm in small swarm configurations, and to film or feature in propaganda more widely.[[17]](#endnote-15) The growing lethal potency of the COTS drone has been recognized, with detailed explorations into their weaponization in the dropping of (targeted) explosives,[[18]](#endnote-16) as well as their fitting with explosives to later detonate when grounded or undergoing forensic investigation.[[19]](#endnote-17) Further, the issue of volume or force multiplication has been raised, with journalists reporting the deployment of small (3 to 5 platform) drone swarms,[[20]](#endnote-18) as well as citing repeated incursions, with “ten quadcopter grenade attacks in one hour” in Mosul, Iraq.[[21]](#endnote-19) While there remain questions of both the non-state actor desired effect of such higher volume or frequency attacks – be they to overwhelm, to distract/ divert, or to prompt psychological distress – and their implications as determined by military personnel beneath them - they nonetheless demonstrate an alternative threat vector and/or disruptor for consideration.

While recognizing the importance of battlefield COTS drone deployments as a drone threat innovation testbed, the following section seeks to re-spatialize and extend such commentary, moving instead to examine homeland COTS drone deployments, and risk potentials therein.

COTS consumer drones are increasing in popularity and accessibility, available from both popular high street and online stores. In Amazon’s online ‘Drone Store’, for example, customers can browse platforms by intended usage category, brand, and price bracket, remotely ordering platforms delivered via a range of global shipping options. In this vein, a 2016 study estimated that around 200,000 drones are sold per month globally.[[22]](#endnote-20) In the United States (US) the growing adoption of COTS drones is evidenced by the registration, by January 2018, of 1 million drones to the Federal Aviation Administration’s (FAA) mandatory scheme, launched in 2015.[[23]](#endnote-21) This situation is mirrored in the United Kingdom (UK), with estimates that around 1.5 million drones were purchased during the 2017 Christmas period.[[24]](#endnote-22)

In parallel with their employment in both commercial and societally-beneficial roles,[[25]](#endnote-23) drones are also domestically associated with a range of ‘rogue’ activities, both nuisance and nefarious. These have included employment as tools in: criminal activity, the surveillance of sensitive sites, flight in close proximity to manned aircraft, and surveillance infractions. Employed by criminal actors seeking to find “novel ways” to transport and smuggle goods, [[26]](#endnote-24) the use of COTS drones in transport of contraband into both prisons [[27]](#endnote-25) and across borders [[28]](#endnote-26) has emerged as a significant issue internationally. Drone scholars have thus asserted that city infrastructures, and the security mechanisms that adorn and encase them, are failing to keep abreast of the drone’s infiltrations, those which “circumvent…current security paradigms.”[[29]](#endnote-27) As is evident in and beyond the battlefield, the ability to carry small amounts of cargo is one which may be further exploited and reimagined to malicious ends in the homeland.

COTS drone platforms have further been used in the rendering visible of sensitive sites, with reports of flights over politically significant sites including the White House, Eiffel Tower, and Colosseum. Unauthorized drones have also been witnessed over both security-sensitive sites such as international embassies and naval/ submarine and nuclear bases - with plants in the UK suffering 37 security breaches in 2014 alone,[[30]](#endnote-28) as well as film sets, corporate sites and sporting sites - with the aim of garnering (commercially) sensitive information.[[31]](#endnote-29) On a smaller scale, COTS drones have been unlawfully flown over specific individuals to ‘spy’ upon them and their financial transactions at cash points (ATMs), in some instances resulting in charges of “voyeurism by electronic equipment”[[32]](#endnote-30). In this vein, the number of public reports to police departments is rapidly increasing, with 2,400 reports of drone incidents to UK police in 2018 alone.[[33]](#endnote-31)

COTS drones have also been enrolled as ‘disobedient objects’ in a range of protest activities. [[34]](#endnote-32) Following in the steps of animal welfare activists in 2012 pursuing a hunting club in 2012, the use of drones by activist groups has since gained ground,[[35]](#endnote-33) with camera-laden drones “beginning to appear in the skies above protests: watching the watchmen.”[[36]](#endnote-34) This was poignantly exemplified at the Dakota Access Pipeline protest, where drones were considered “invaluable in recording…abuses” associated with non-lethal policing measures.[[37]](#endnote-35) Further, COTS drones have also been mobilized in relation to political figures. For example, at a 2013 campaign rally members of the Pirate Party flew a drone towards German Chancellor Angela Merkel in protest of surveillance legislation. Such actions demonstrate the potential risk COTS drones pose to political leaders, and the airborne challenges faced by those responsible for maintaining their safety.

The notion of deploying drones with the aim of causing disruption remains an idea that has since morphed, re-appearing in different guises. In December 2018 Gatwick airport captivated global headlines following reports of drone presence above the airfield. While affecting 140,000 passengers, any operator(s) continue to evade prosecution.[[38]](#endnote-36) Further, in April 2019, consultation documents circulated between members of the climate change activist group Extinction rebellion reportedly detailed plans to use drones at protests at London’s Heathrow airport.[[39]](#endnote-37) Alongside disruption via presence, protest groups have also used COTS drones in the transport and delivery of materials. The activist group Women on Waves, for example, used drones to deliver termination pills from Germany to Poland in protest of abortion legislation.[[40]](#endnote-38) This incident reveals and reminds of the drone’s ability to traverse (some) borders, whilst outfitted with a carrying load, with, at times, relatively unrestricted movement. Further, in 2015 a drone outfitted with a small parcel of radioactive sand was flown onto the roof of the Prime Minister of Japan’s office by an individual protesting the administration’s nuclear energy policy.[[41]](#endnote-39) This incident highlights a broader concern around the outfitting of COTS drones with hazardous materials. Of note here is the lineage of the non-military drone as a precision farming device: one long-deployed as an agricultural tool to more-rapidly, target, and disperse pesticides and fertilizers. In thinking with the COTS drone as a potential threat, it is important to note existing associated usages and the ways these could be reconfigured and exploited: in this case though a re-imagined dispersal mechanism. While this impulse is arguably already manifest in the 2018 deployment of tear gas equipped drones piloted by Israeli border police over the Gaza border,[[42]](#endnote-40) concern is more widely vocalized around the fear of the “marrying[ing] together [of] two technologies – drones as a dispersal device and chemical, biological or radiological material as the dispersant”[[43]](#endnote-41) and the subsequent deployment over a “political rally in a Western state”.[[44]](#endnote-42) While it has been noted that “a chemical attack is not necessarily an easy thing to do”, drone scholars nonetheless caution that groups such as the IS are associated with a history of chemical weapons usage, and the drone could become an iteration in this lengthier story.[[45]](#endnote-43) When considered with the observation of US Air Force researcher Ellis that given the relative unavailability of “CBRN agents” non-state actors may turn instead to less secure “materials similar to CBRN” such as “commonplace industrial chemicals, biological contaminants, and radioactive materials”,[[46]](#endnote-44) concern surrounds a re-imagined drone being paired with a re-imagined harmful agent. Anxieties around the outfitting of drones with hazardous materials have been echoed by both military forces and political leaders alike. Conducting an aerial threat assessment ahead of the 2012 Olympic Games in London, for example, the British Army asserted that it was “feasible” that a COTS drone could be outfitted with poison and used as a “biological weapon in the capital.”[[47]](#endnote-45) Similarly, in a gathering of world leaders the possible drone “transport [of] radioactive material into the heart of major cities” was referenced.[[48]](#endnote-46) In thinking further with this threat it remains important, then, to acknowledge an emerging DIY threat character, and the challenges of its governance given its status as (and/ or pairing with) multi-purpose (materials).

Thinking across this section’s collection of aerial incursions, the drone, then, can be understood as variously disruptive, deployed as both a subversive and/or criminal assistant and surveyor. Flexible in purpose, COTS drones can be employed in both the capture of sensitive data, and as a presence in the sky to disrupt, damage and challenge diverse atmospheres, crowds, and spaces below. Such threat potential should also be considered alongside the growing number of COTS drone flights in close proximity with manned passenger aircraft. This issue continues to be hotly debated, with the US reporting 188 near misses between drones and manned aircraft from August 2015 to January 2016, and the UK reporting 120 near-misses between December 2017 and December 2018. A report describing one such incident details pilots purportedly seeing a drone at 10,000ft, around 98ft from their aircraft when preparing to land into Heathrow airport.[[49]](#endnote-47) While persistently reported as reckless flying, such instances nonetheless retain a notable potential threat, one arguably outpacing research seeking to model its anticipated effects, with the European Aviation Safety Agency stating that there remain “few conclusive studies available”[[50]](#endnote-48) in this area.[[51]](#footnote-3) Such close-calls arguably highlight a threat potential in both the disruption of existing airspace operations, and a potential for a harmful collision therein. While attempts at mitigation at airport sites are under development, these remain sporadically deployed, marking various levels of successful implementation, and not yet extended to cover all transport infrastructures and hubs.

This section has highlighted that while domestically-deployed drones are, at present, responsible for the infliction of far less harm than their battlefield counterparts, they nonetheless remain tied to ashared risk potential. Profiling a selection of existing usages, it is demonstrated that they are inherently *malleable objects* - variously, multiply, and creatively deployed – in an impulse that can be alternatively read in terms of threat potential. This malleability is amplified and complicated by a further tension that defines the drone: while they are increasingly understood as (potentially) risky objects, so too are they understood as increasingly valuable operational assets, deployed in the very provision of aerial policing and security more widely. For example, a reported 910 US state and local police, and wider emergency service agencies, have acquired drones, [[52]](#endnote-49) a figure echoed in the UK with a reported 31 of 45 police forces owning or having access to drone technology.[[53]](#endnote-50) The drone then, remains at once both a *policing assistant* and one *to be policed*. While such multiple identities demonstrate the drone’s status as a multi-use technology, it remains important to note that it is not alone as a device which might be alternatively and subversively mobilized as a terrorist tool. From cars repurposed to strike crowds to “ordinary household materials” nefariously recycled as improvised explosive devices,[[54]](#endnote-51) objects that surround us have of course long been within the purview of terrorist experimentation and innovation. While not within the scope of this article to think across the range of technologies that might fall within a discussion of weaponized modification for the infliction of harm, where it would like to offer contribution is in thinking with *malleability* itself. Defined in the dictionary in two parts, to be malleable is to be (as individual or being) “easily influenced – pliable” or (as material) “able to be hammered or pressed into shape without cracking”.[[55]](#endnote-52) Both definitional forms offer something to a discussion of the malleable drone; it is, after all, a pliable device pressed and pressured into different shapes, and one encased by a dynamic and evolving imagination that surrounds its multiplicity. While this definition arguably nicely encapsulates the drone, its mention of ‘not cracking’ elides the tensions, fractures, and contradictions that increasingly surround the drone. In what follows, in approaching the drone at a series of alternative sites, the article thinks with this expanded definition of the malleable consumer drone, in order to examine specifically its multiple, emerging, and at once fractured character.

**Drone evolutions: Trends, spaces, temporalities**

Understanding drone innovation as a “moving target”,[[56]](#endnote-53) the article now turns to examine evolutions in drone capability, culture, and context. In so doing, it approaches the drone at three constitutive sites: *developmental trends, spaces,* and *temporalities,* tracing (potential) drone risk therein. The first section (*trends*) profiles key industry innovations highlighting both the changing movements of the drone, and the ways in which these are supported and extended online. The second section (*spaces*), through the lens of the increasingly popular space of ‘do it yourself’ (DIY) droning, examines instead examines user and community-driven drone experimentation. The final section (*temporalities*) argues that the drone should also be considered at different points within its life-cycle. Here, in discussion of supply chains and anticipated drone futures, it seeks to alternatively extend discussions of drone risk from the incident to antecedent and succeeding conditions surrounding it. In approaching these three sites through which the drone is variously constituted, drone risk is teased out, as is the fundamentally malleable character of the drone further reflected upon.

***Developmental trends***

***Intelligent flight***

A developmental trend of capability note lies in the area of ‘intelligent flight’, referring to particular flight modes and capacities. While at present limited to market leader DJI’s drones, such capabilities are notably increasing the sophistication and scope of drone flight and maneuver. Initially launching a range of ‘intelligent flight modes’ in 2015, a number of DJI drones enable their users to: lock onto and follow particular points, objects, and, persons, as well as to increase speed or ascend/ descend rapidly therein.[[57]](#endnote-54) While these features are billed as cinematographic techniques to aid leisure and sports users in capturing artistic shots, the tagline of ‘take off, target and go’[[58]](#endnote-55) remains indicative of the potential of such capabilities to be nefariously repurposed: that is made harmful or weaponized. In addition to employing the discourses of precision targeting associated with contemporary drone warfare, such COTS drone features also arguably echo facets of warfare practice itself, those premised upon the (geo)location, tracking, and targeting of a suspect. Developed as such, ‘intelligent’ COTS drones may harness a potential to make easier or re-spatialize the identification and tracking of ‘targets’, with hovering or loitering capabilities enabling the ability to wait for a particular moment or opportunity to ‘strike’. Concerns around such latent risk potential are expressed in a 2018 report by the National Academies of Sciences, Engineering, and Medicine, with authors asserting that such flight modes invite “creative thinking and engineering” that could pose “significant threat”.[[59]](#endnote-56) While, at present, such capabilities remain primarily available on higher price-point COTS drones, these are likely, over time and driven by consumer interest, to be scaled down and expanded. This marks a notable capability evolution, particularly within a wider environment of drone navigation innovation, with unfolding developments in both obstacle avoidance (detect and avoid objects) and navigation in GPS-denied environments.[[60]](#endnote-57) While comparatively nascent navigational capabilities, they remain indicative of the changing abilities of the drone to better ascertain and respond to particular, and even restricted, environments. This *capability* arguably remains bound to a *risk potential*, of a drone to identify, follow and potentially target (a person or object), or conversely to evade (e.g. a defence infrastructure), more easily.

***Sociality***

A further notable developmental trend is that of image and video sharing, particularly broadcasting via social media. In 2016 Facebook teamed up with market leading drone manufacturer DJI to launch a live-streaming feature between particular drones and a user’s profile, [[61]](#endnote-58) a feature subsequently rolled out to Periscope (acquired by Twitter). Further, more recently cell (mobile) phone company Huwaei demonstrated a new feature enabling select drones to “make video calls” (in real-time) to their EMUI 10 smartphone.[[62]](#endnote-59) While in each instance presently paired with higher-end COTS drones, such features are likely, following consumer demand, to be more widely rolled out. Thinking with potential risk, and scholars asserting a need to acknowledge the “*optical* character” of terrorism, the “immediacy” and accessibility of imagery remains an important consideration here.[[63]](#endnote-60) While of course distinct to the surveillance and data capture of the military drone, COTS drones share the ability of both providing actionable aerial imagery to inform operations and collecting footage which can be otherwise disseminated for *propaganda* purposes. With broadcasting developments, the drone could be *alternatively* weaponized – not just in the direct infliction of harm, but also in its *live capturing*, broadcasting this (or e.g. flights in “contested” locations, or visualizing other modes of attacks), in order to provoke “a significant propaganda victory.”[[64]](#endnote-61) Seeds of such weaponization are evident in the IS’ release of a series of propaganda videos featuring quadcopter-released munitions; in some instances using a COTS drone to film another COTS drone releasing “a small bomb tucked in its fuselage.”[[65]](#endnote-62) Whilst cognizant of the limitations that surround the live broadcast functionalities at present (in terms of both platforms equipped, and connectivity required), the potential power of *live* attack should not be underestimated, particularly as it would act to disrupt and subvert the entrenched iconography of the military drone’s asymmetric intervention. In other words, “the symbolic value of giving America a taste of its own medicine might be appealing,” with the COTS drone acting as a means through which to do so.[[66]](#endnote-63)

***Developmental spaces***

Alongside developmental trends, developmental spaces mark a further site through which the drone, and drone risk, are constructed. This section focuses in on one key under-examined space, that of ‘do it yourself’ or DIY droning.

***DIY drones***

Accompanying the increasing popularity of the drone as a commercial and civilian tool, there is a growing community of DIY drone enthusiasts, comprised of hobbyists, amateurs, artists, and gimmick actors, each enjoying modifying and tinkering with drones. Spawned in part from the growing availability of drones, a creative “do-it-yourself ethic” has emerged, leading to a range of “noteworthy innovations.”[[67]](#endnote-64) As drone researcher Don Rassler notes, the DIY community provides a “firm baseline” for understanding improvised innovation, that which can potentially expand the “capability profile of drones” as deployed by “a terrorist entity.”[[68]](#endnote-65) As such, a range of DIY drone modifications are now outlined and read in relation to threat potential.

As the drone’s prevalence has grown, so too have hobbyist desires to modify the platforms to carry novel payloads. In one highly publicized case, a US teen was expelled after releasing a video featuring a drone he had outfitted with a functioning semiautomatic handgun. The same individual later outfitted a drone with a functioning flamethrower, demonstrated cooking a Thanksgiving turkey.[[69]](#endnote-66) This spirit of modification is, however, by no means limited to a single teen. ‘Game of Drones,’ for example, is an online show in which a small US team “design, build and fight” drones, equipping the platforms with a range of kinetic materials, including fire, rockets, explosives, and paintballs, underpinned by the (rather facetious) aim of showing its audience “how much fun aerial combat can be for the whole family.”[[70]](#endnote-67) As the show’s presenter remarks, the team were “curious about the super cheap and super tiny quadcopters flooding the market” and wanted to “push further” their capabilities through a series of modifications.[[71]](#endnote-68) In one instance the team outfit a drone with a paintball gun, wirelessly connected to a hand-held trigger, allowing the “gunner to…look down the barrel…in real-time at his target” (a man running away from the device).[[72]](#endnote-69) Delving further the online video host’s Youtube search results, the impulse to weaponize drones is further highlighted by a group of Finnish filmmakers creating the ‘killer drone’, an octocopter equipped with a fully functioning chainsaw.[[73]](#endnote-70) Lastly, others experimenting with the drone’s capacity to roam whilst carrying a weapon have outfitted drones with tasers, with one able to shoot “barbed taser darts at a target, delivering up to 80,000 volts” of electricity.[[74]](#endnote-71) While quick, in the majority of cases, to communicate that such drone users have “no plans to…commercialize” such modifications,[[75]](#endnote-72) this suite of examples nonetheless collectively demonstrate both experimental weaponizations, potential inspirations for improvised capabilities, and the sharing of designs online.

When writing of improvised weaponization it remains pertinent to note that the desires of both the DIY community, and non-state actors on the battlefield, to outfit the drone as such can be situated within a wider cultural imaginary surrounding the drone. This spans both the history of military forces deploying drones as target practice, ‘flying bombs,’ and reconnaissance platforms,[[76]](#endnote-73) and the domestic operationalization of policing drones. Here, alongside use as image capture/surveillance devices, police forces have also experimented with *non-lethal* payloads, including forces in India deploying pepper spray-equipped drones,[[77]](#endnote-74) the marketing of drones that “deliver canisters of tear gas, or smoke grenades for ‘crowd control’”[[78]](#endnote-75), and unfolding regulatory exemptions for police in the outfitting of drones with weapons.[[79]](#endnote-76) While designed to “subdue civil unrest,”[[80]](#endnote-77) the imaginary that surrounds weaponized drones arguably travels further than such uses. It could thus be argued that efforts seeking to *securitize with the drone*, may (albeit inadvertently) inspire or feed into malicious innovations and imaginations more widely.

Beyond experimental weaponization, the DIY community also includes a range of more ‘playful’ interventions. Enthusiasts have equipped drones with fireworks, filming them chasing people on the ground. [[81]](#endnote-78) Similarly, the creative team at Chaotic Moon Studios have outfitted drones with silly string and graffiti (pre-programmed to spray-paint designs). This artistic ethic is echoed by Tilt, who developed a team of racing drones to construct and decorate a cake.[[82]](#endnote-79) The platforms work together, lifting items, and making use of the improvised appendages - ‘canons’ and ‘guns’ discharging lightweight objects and substances, as well as a flame thrower lighting the candle atop the cake. While ‘playful’, such modifications demonstrate how the drone can be creatively made alternatively capable. Whether through the addition of (flammable) releasable objects/ substances (solids, liquids, gases) or the act of drones working together in swarm formations, these adaptations could potentially be reimagined and repurposed, in the infliction of harm – the drone’s inherent malleability creatively attractive yet potentially subject to manipulation.

DIY drone innovations are however not limited to physical modifications of the payload, but rather also include experimentation with the (limits of) the drone itself. A hobbyist captured the headlines after anonymously publishing a video of a COTS drone flown at over 11,000 feet over an unspecified European city. At this height, one far beyond common regulatory ceilings, DJI software restricting flights at this altitude will have been disabled.[[83]](#endnote-80) This demonstrates both the drone’s potential mobility, and the ability to hack particular features, together opening up distinct spaces and verticalities to potential threat. In otherwise seeking to increase the capabilities of COTS drones, enthusiasts have also modified the drone’s frame. In the increasingly popular ‘aerial sport’ of drone racing, modified drones are flown around racecourses, featuring navigation and obstacle challenges, and involving flying at up to 160 miles-per-hour. Collectively, such platform modifications can be read as variously potentially threatening. In skilled hands, such drones could harness the potential to more effectively (in terms of precision, speed, and form of engagement) penetrate, distract or overwhelm defensive cordons, or target an individual.

In closing this reflection, and building upon aforementioned discussions of sociality, it remains important to note that the DIY community is increasingly well-resourced online. On the international forum, DIY Drones, for example, enthusiasts can join over 83,000 others in open forum discussions of platform capabilities and comparisons; hardware, software and wider requirements, issues and fixes; and the sharing of individual projects. Alongside additional digital tutorial websites, such sites act as crucial dissemination and educational tools. Here we can turn to the example of bomb and suicide vest building resources online, those with which terrorist actors have long-engaged. As Peters notes in discussion of Jihadi communications, there remains a relative dearth of academic attention to such ‘instructional spaces’, in spite of their pivotal role as resources playing “a key role in the rhetorical transfer of knowledge”.[[84]](#endnote-81) As with physical drone training grounds, online spaces then are important virtual grounds from which to potentially develop a weaponized drone tradecraft, and those about which mitigation lessons can be learned from wider terrorist resource communities.

This section has sought to make visible a range of unusual, creative, and experimental ways in which ordinary citizens have modified and used drones, approaching such improvised innovation with a view of anticipating potential threat therein. When considered alongside the growing presence of Jihadi-authored drone materials featuring across social media,[[85]](#endnote-82) it remains pertinent for COTS drone thinking to attend to both the drone itself, and the knowledge sites and cultures surrounding it.

***Developmental temporalities***

This section approaches the drone instead at key developmental temporalities, asserting that it remains important to consider it at different points within its life-cycle. In so doing, it highlights that drone risk materializes and manifests beyond the site/ space of a drone incident.

***Drone pasts: Components and supply chains***

The supply chain is understood as an important preceding temporality enabling and facilitating non-state actor drone use. This was brought to the fore with the September 2018 arrest of two individuals in Denmark, charged with “attempting to supply” the IS with drones.[[86]](#endnote-83) While a notable event itself, more significant was the wider network within which these individuals were acting. This network is examined by drone researcher Don Rassler who acknowledges that while the IS remains “known for doing things a bit differently”, the group’s “capacity for innovation” remains significant and may inspire drone innovation beyond it.[[87]](#endnote-84) In particular, Rassler notes IS’ ability to “bring its programme to scale in a relatively short amount of time”.[[88]](#endnote-85) A key facet of this scaling was the group’s ability to acquire COTS drones through a vast “global and layered supply chain” inclusive of purchases from at least 16 companies in at least 7 countries.[[89]](#endnote-86)

Thus, while the effects of a drone incident may be felt locally, the (re)sourcing which underpins it can, in this case, be understood as an international issue. Thinking further with the supply chain as a formative temporality, it is also important to note IS’ bureaucratic strides in formalizing drone use, those which alternatively enable drone use to be scaled. This process has included the establishment of small ‘factories’ in which drones have been modified and built [[90]](#endnote-87) as well as the formation of a dedicated ‘Unmanned Aircraft of the Mujahideen Unit’, each underpinned by documentation demonstrating “an elaborateprocurement system…[and] extensive procedures for altering and testing the equipment”.[[91]](#endnote-88) Such facilities have been described as representing the “group’s attempts to build their own makeshift Air Force”.[[92]](#endnote-89) These formalization steps are significant as they signal both a shift from “one-off” drone incidents to a more methodical approach,[[93]](#endnote-90) and the role of resourcing - paperwork, plans, blueprints - that which can be more widely shared online – thus expanding and re-spatializing access to materials enabling potential drone threat. While a notable example, it should be added that IS’ level of resourcing remains somewhat atypical. In thinking then instead with such temporalities and *different scales* of operation (e.g. lesser resourced, smaller or lone wolf conducted incidences), we might highlight alternative avenues of supply and access. Thinking with second hand devices available on platforms such as Facebook Marketplace and Gumtree, further muddies any establishment of resourcing – that which remains challenging at multiple scales.

***Drone futures: Projected and anticipated airspace***

A further way in which to think about the emerging drone is turning to the ways in which drone futures are anticipated, with an eye to thinking about how drone risk may itself evolve in an evolving airspace. Beyond the battlefield, drones are increasingly being deployed, trialed, and anticipated in a range of applications. Across a range of industries (including infrastructure, transport and delivery, media, agriculture, security), drone powered solutions have been attributed with a potential value of $127.3bn USD.[[94]](#endnote-91) Within such future-orientated projections and forecasts anticipating large-scale drone operations, an evolving, even transformed airspace is presented. This is (slowly) beginning to materialize, through for example the operationalization of select delivery drone programmes designed as ‘last mile’ solutions (Switzerland are particularly active in this space), [[95]](#endnote-92) the growing use of drones to survey and inspect infrastructure, and the use of drones of emergency contexts.[[96]](#endnote-93) While resourcing seeking to aid the integration of drones, *at scale*, into airspace continues through a range of international initiatives,[[97]](#endnote-94) challenges around both the complexities of the development and implementation of airspace traffic management systems (Unmanned Traffic Management, UTM), and its limitations in relation to ‘non-cooperative’ drones,[[98]](#endnote-95) nonetheless largely persist at present.[[99]](#endnote-96)

While still very much an emergent, evolving, and unfolding space, the future drone city landscape is nonetheless a notable temporality to consider. Thinking with such projections of potential drone futures, we can think also, speculatively, with evolving drone risk in evolving airspace. For example, the wide-scale integration of drones represents a series of challenges around competition, complexity, and congestion. With the morphing of airspace, so too might there come the morphing drone risk. For example, following both incidents and plans for the deployment of drones to cause *disturbances*,[[100]](#endnote-97) in a different, busier, airspace we might see an alternative form of drone risk emerge: *deception.* As a growing number of certified drone users emerges, this evolving airspace condition could be exploited, with a nefarious user copying the platform markings and/or duplicating the flight patterns of legitimate users in order to cause confusion. This is not to eschew developments in the ability to identify drones in airspace (known as electronic identification or conspicuity), but rather to flag that as the composition of airspace may change, so too might different forms malicious drone deployments emerge. After all, just as examining the drone and its wider communities has aided in the sketching out of emergent and evolving potential drone threat, so too can examining alternative sites of formation and foundation.

**Evolving risk, evolving mitigation**

Thus far this article has reflected upon potential drone risk through a series of sites acting to construct the drone, revealing its multiple, malleable and evolving character. As drones, and the risks that may reside within and resultant from them evolve, so too do efforts to counter them. This section thus provides a brief profile of extant and unfolding techniques of drone mitigation, and some challenges that surround them. Such approaches, known as *counter-measures*, each distinctly seeking to “manage, track, and degrade” drone threats.[[101]](#endnote-98)

Existing counter-measures can be broadly divided into two strands, namely regulatory and legislative, and technological. In the first instance, domestic legislation is increasingly being put in place, seeking to “target the full supply chain and life cycle of [COTS] drones.”[[102]](#endnote-99) The cornerstone of drone legislation is that issued by national civil aviation administrations or authorities. While approached differently globally, 32 countries presently legislate in this manner, either emplacing different altitude and weight restrictions, or opting for an outright ban on platforms.[[103]](#endnote-100) In the case of the US, for example, the Federal Aviation Administration (FAA) specifies rules (for leisure flight) including device flying height; proximity to aircraft, locations, and people; and requiring that the drone is flown within operator visual line of sight. In a further attempt to ensure safe and responsible flight, in December 2015 the FAA initiated a mandatory drone registration scheme. While suffering some set-backs,[[104]](#endnote-101) as an approach, mandatory registration has continued to prove popular, adopted by Russian, Italian and Irish aviation authorities, and shortly so (November 2019) in the UK also. Educational initiatives lead by national airspace regulators are also proving increasingly popular as an approach seeking to inform drone users of relevant regulation and related safety issues. In the UK the Civil Aviation Authority launched the ‘Drone Code’ Campaign, one featuring a concise summary of required rules, resources, and details of a smart phone app hosted by the UK Air Traffic Control provider. While laudable as attempts to make better knowable and respond to the growing presence of drones in airspace, such proposals nonetheless require participation and adherence, leaving them liable to non-conformity: both reckless and careless or malicious.

Here, a related issue arises in the policing and enforcement of relevant regulation. Within the UK the growing availability of drones has been accompanied by a 40% rise in reports of drone incidents to police forces (2016 - 2018).[[105]](#endnote-102) Given this rise, and high profile drone incidents at UK airports, the Government has instituted the extension of restriction zones around aerodromes and the granting of additional powers to police enforcing drone misuse.[[106]](#endnote-103) Much like tackling unlicensed car drivers, there remain particular challenges in policing illegal and rogue drone activities. These include the distance at which drones can be operated, their ability to follow pre-programmed flight paths, (ambiguous) carrying capacity, the (potential) anonymity of devices and operators, challenges of discerning intent, and growing accessibility of both platforms and supporting resources/ spaces. While asserting that the drone mitigation picture remains a complex one, it should be noted that there have been prosecutions, particularly in the area of the use of drones to transport contraband into prisons – an issue aided by the formation of both Police-Force and cross-department governmental squads (eg. in Japan and the UK). Further, a range of wider parliamentary responses have emerged, with the UK House of Commons Defence Committee currently undertaking an inquiry into ‘Domestic Threat of Drones’, examining both drone threat and “the UK’s preparedness for responding” to it.[[107]](#endnote-104)

Such regulatory approaches to drone risk mitigation are accompanied by a growing panoply of *technological counter-measures*. This can be understood as a burgeoning space, comprised of over 230 solutions developed by 155 manufacturers in 33 countries.[[108]](#endnote-105) Such technological responses differently seek to: 1) detect and identify drones, 2) impede and halt drones, or 3) neutralize and interdict drones. Such counter-measures can also further be divided into measures embedded into the device (developed by drone manufacturers), and those external to the device (developed by counter-measure manufacturers).

Following the logic that drones render “airspace…exposed”, [[109]](#endnote-106) a series of devices *external* to the drone have been developed.The first set of *external* counter-measures aim to *detect* the presence of a drone within a defined perimeter and *alert* the system owner to this intrusion, in real-time. Such measures incorporate a range of sensors including: acoustic sensors to detect drone signatures, microphones, radar and infra-red to detect small targets, and/or use radio frequency detection (RF) to identify emitted signals, allowing detection at different ranges. These systems are intended to discern between drones and other airborne objects/ animals by comparing object signatures to those in an established database. More complex systems are marketed on the proviso that they can also assist in assessing the threat of the drone, tracking for example its movement patterns, speed, and payload-carrying capacity. This form of detection is understood as a significant form of protection because of both the difficulties of seeing a drone at a ‘hovering height’ of above 100m,[[110]](#endnote-107) and the provision of an opportunity to “react and limit the potential for harm.”[[111]](#endnote-108) Acknowledging this, drone manufacturers DJI have themselves developed a system, ‘Aeroscope’ which allows airports and police “to determine the location, direction, altitude and serial number” of local DJI drones.[[112]](#endnote-109) Collectively, *Detect and alert* systems can be understood as “passive” counter-measures, meaning that they solely register the drone’s presence without actively engaging or interacting with it.[[113]](#endnote-110) Such systems tend to feature: radar, radio-frequency, electro-optical, infra-red, acoustic and combined sensor approaches.[[114]](#endnote-111)

The second set of *external* counter-measures seek instead to *impede and halt*, that is more actively interdict, the drone’s functioning. These include GPS jamming, radio-frequency jamming, and geo-fencing methods. Jamming, for example, involves breaking the command link between the drone and its controller. Jamming takes several forms, including both GPS Jamming, as employed by Battelle’s ‘Drone Defender’ rifle, and radio-frequency jamming, as employed by Blighter’s Anti-UAV Defence System (AUDS), emitting a directed signal to disrupt the drone’s communications. In interfering with and blocking the drone’s control signals, such counter-measures force the drone into following its designated safety protocols, those which include either hovering in place, attempting to land, or returning to the point of launch. While considered a more safe and controlled response, it has been noted that such signal blocking devices are both stringently regulated, and where permitted for use, can pose issues to wider signal-reliant devices.[[115]](#endnote-112) Lastly, frequency hopping – as present in safety features increasingly embedded within particular COTS drones – may inadvertently make drones harder to jam.

Geo-fencing refers instead to the erection of an invisible electronic fence preventing drones from entering electronically cordoned-off areas. In 2017 a British prison was to become the “world’s first” to employ a geo-fenced ‘drone shield’ (produced by Sky Fence) acting to both “detect and deflect” drones within a radius of 2,000ft around the facility.[[116]](#endnote-113) Geo-fencing can also be *embedded*, by the drone’s manufacturer, into the drone’s firmware, acting to “force the drone to ground” should it “trespass” a defined boundary,[[117]](#endnote-114) such as a politically sensitive location or airport. This approach remains relatively limited to higher-end COTS platforms, with DJI designating over 350 geofenced sites globally, as well as battlefield locations in Syria and Iraq in response to IS’ use of their platforms therein. While initially applauded, DJI subsequently fell prey to criticism because such measures required user cooperation, internet connectivity to download updates, and remained susceptible to forms of disabling/ override. DJI has since improved and extended its geofencing, in 2019 launching Geospatial Environment Online 2.0, a pan-European geofencing initiative covering 32 countries.[[118]](#endnote-115)

The final set of *external measures* seek instead to kinetically *neutralize, interdict* or down the potentially threatening COTS drone. The most basic approach employed has been the use of projectiles, with individuals shooting down drones above their property, and this being (facetiously) commodified by companies selling ‘Drone Munition’.[[119]](#endnote-116) Projectiles have been accompanied by more sophisticated industry-developed counter-measures, seeking instead to down drones by *intercepting* them in a more controlled manner. Approaches have spanned portable net-firing guns ensnaring drones, drones affixed with nets to catch other drones, and the training of eagles to snatch them from the sky.

While it is anticipated that a range of such technological counter-measures profiled will become “entrenched in the city,” they remain at present an unfolding form of response [[120]](#endnote-117) - remaining in the early stages of development - learning, responding and adjusting to complex and congested operational landscapes. Issues thus remain around system cost and effectiveness, patchwork installation/ adoption, and the legalities of employing devices with different engagements in the electromagnetic spectrum.[[121]](#endnote-118)

**Conclusion**

This article responds to a changing drone landscape, shifting discussions from battlefield drones, to examine an alternative and increasingly significant site within the wider drone ecosystem: the domestically-deployed commercially-available off-the-shelf (COTS) consumer drone. Increasing in availability and accessibility, the COTS drone has captured the eye of a growing diversity of domestic users. As is profiled, a diversity of non-state actors have enrolled drones into a range of terrorist, criminal, reckless, as well as creative and subversive activities. Alongside profiling existing drone threat therein, this article highlights that the consumer drone’s very malleability – in function, form, application and purpose, necessitates a wider look to associated capabilities, spaces, and knowledges, in order to more fully, and creatively, sketch out potential drone risk.

Approaching the evolving consumer drone through a series of sites through which it is both technically and socially constructed, the article first identifies several pertinent *developmental trends*. While cognizant of need to recognize current platform limitations in range, flight time, and carrying capacity – so too is it important to note that drones remain nonetheless multiply capable – flying in growing and changing ways, at different angles and altitudes, and with different flight patterns. Here, I examined industry-driven consumer drone innovation in the area of intelligent flight, raising questions of changing, charging, and potentially contentious aerial maneuvers. Turning to developments in broadcast functionality, it highlighted that in the drone’s “novel abilities to see and visualise”[[122]](#endnote-119) arguably lies dormant the potential for amplified imaging and propaganda. Further, security agencies such as the Department of Homeland Security are increasingly warning of the use of drones in the committing of “cyber crimes” such as the “theft of…sensitive information”. [[123]](#endnote-120) While extant discussions vary in the sourcing and resourcing, and sophistication, scope and (in)accessibility of capabilities associated with such potential attacks,[[124]](#endnote-121) security practitioners nonetheless recount smaller-scale instances in which DIY “wifi sniffer” drones equipped with COTS parts may be deployed in delivery of a “cyber effect”.[[125]](#endnote-122) It thus remains pertinent to think also about the drone’s ability to *see otherwise* – that is to sense and render visible non-visible data landscapes.[[126]](#endnote-123)

Turning then to explore key *developmental spaces* through which the drone is constructed, the article engaged instead with consumer/ drone user-borne experimentation. Here, it focused on the oft-overlooked DIY community as a lens through which to explore ‘improvised innovation’. This focus brings to mind recent calls of Macdonald and Schneider for a greater attentiveness to the role that ‘users’ play in understanding and constructing emergent warfare technologies.[[127]](#endnote-124) While their analysis is centered upon the experiences and perspectives of ground military drone personnel, the recognition that “there remains a striking lack of attention to the human element” in discussions of technological adoption and adaption [[128]](#endnote-125) is a welcome invitation to call too here for further work that empirically examines the multiple and often conflicting ‘user’ communities – from military to DIY - that (albeit differently) inform drone knowledges and deployments. Here, reflections should, as drone researchers note, take seriously the drone “end user’s needs, goals, and capabilities”, rather than simply deterministically fetishizing the technology itself [[129]](#endnote-126). Taking seriously the ideological underpinnings of non-state actor and terrorist groups, and how these may inform the “tools they select to pursue their objectives” remains important.[[130]](#endnote-127) Rather than seeking to be deterministic about techno-risk inevitability, this article follows Don Rassler in asserting the value of taking seriously the emerging culture of creative drone experimentation and modification, and the ways in which such adaptations and re-purposings *could* potentially mark evolutions or inspirations in drone risk too.[[131]](#endnote-128) Here, it can be reiterated that such user-borne experimental innovation is importantly resourced and amplified through specific sites (both physical and virtual) of knowledge circulation, exchange and learning. From online drone communities and networks, to physical training and flight spaces – the drone is encased by a wide network of instructional and inspirational spaces – those which the article suggests warrant further engagement by defense and security practitioners and scholars alike.

Lastly, in thinking more widely with the drone’s resourcing, the article turns to particular *developmental temporalities* - of the supply chain and future drone city. Here, it seeks to remind of attending to consumer drone evolutions at a range of points and periods. After all, while the “content of technology” is important, so too are the supply networks and “alliances” underpinning it, [[132]](#endnote-129) and the visions and anticipations that continue to fuel its investment.

While following calls for the mapping of COTS drone risk in both ‘proactive’ and ‘imaginative’ terms, [[133]](#endnote-130) the article of course recognized ongoing attempts to counter and mitigate it. In profiling extant counter-measures, it highlighted the complexities of implementing protective measures in both an evolving marketplace and airspace. If we are to assert that while “drones may now still be a rare sight in the sky, it is expected that within a few years, there will be plenty,”[[134]](#endnote-131) our understandings of COTS consumer drones must thus remain attentive to both *drone potential* and *potential drone threat*. This article has thus sought to highlight the drone’s malleability – in application, form, purpose, intent, knowledge mobilization, and evasion from countering – as one key avenue through which to continue its interrogation.

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