# *Drone sensing volumes*

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**A R T I C L E**

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**Anna Jackman** ⬤

University of Reading, UK

**Correspondence**
Anna Jackman, University of Reading,
Russell Building, Whiteknights,
Reading, RG6 6DW, UK.
Email: a.h.jackman@reading.ac.uk

**Abstract**

We are in the midst of a global turn to the drone. Following their establishment as icons of contemporary warfare, drones are increasingly deployed in a range of more-than-military applications. Interrogating this diverse ecosystem of platforms, scholars have examined the ways in which drones see, sense and manoeuvre, asserting that they enable distinct perspectives and the rendering visible of expanded and extended sensory terrains. In parallel, scholars from across and beyond the social sciences are increasingly mobilising the concept of volume to (re)consider conceptions of space in three-, rather than two-dimensional terms, with complex heights and depths. Thinking at the intersection of these discussions has explored drones as at once acting in, enacting, capturing and comprising volume. This paper extends these discussions by foregrounding drone sensing volumes and the diverse visualities, practices and relations they compose and comprise. Through the lens of drone sensing volumes in the context of emergency—and specifically through the snapshot example of sensing for signs of death following a homicide—the paper understands the sensor-laden drone as a volumetric project both demonstrative of diverse sensing sensibilities and prompting a thinking otherwise of volume. While existing scholarship importantly attends to the conflict, control and calculative dimensions of volume, this paper mobilises the snapshot of drone sensing as an invitation for further attention to diverse forms of techno-instrumentalisation, and the accommodation of more diverse drone sensing sensibilities that seek to resolve, rather than to perpetuate, volumetric violence.

**K E Y W O R D S**

death, drones, homicide, sensing, UAV, volume

## 1 | INTRODUCTION: UNDERSTANDING DRONE SEEING-SENSING VOLUMES

This paper explores drone sensing volumes and the diverse visualities, practices and relations they compose and comprise. It engages, brings into dialogue, and extends existing work in the areas of drone geographies and volume. As this extended introduction outlines, within and beyond the field of drone geographies, scholars have interrogated the ways in

which drones see, sense and manoeuvre, asserting that they enable distinct perspectives and enact the rendering visible of expanded and extended sensory terrains. In parallel, scholars from across and beyond the social sciences are increasingly turning to the concept of volume to (re)consider conceptions of space in three-, rather than two-dimensional terms, with complex heights and depths. Thinking at the intersection of these debates understands drones as at once acting in, enacting, capturing and comprising volume. Extending these discussions through the lens of drone sensing volumes, this paper foregrounds drone sensing in the context of emergency, turning specifically to the snapshot example of drone sensing for signs of death following a homicide. In so doing, it interrogates the sensor-laden drone as a volumetric project both demonstrative of diverse sensing sensibilities and prompting a thinking otherwise of volume more widely. While, as is shortly unpacked, existing volumetric scholarship largely attends to the conflict, control and calculative dimensions of volume, this paper mobilises a snapshot example of drone sensing as an invitation for further attention to diverse forms of techno-instrumentation, and the accommodation of more diverse drone sensing sensibilities that seek to resolve, rather than to perpetrate, volumetric violence.

It continues to be asserted that we have entered a 'drone age' (Coley & Lockwood, 2016). Following the cementing of a now established literature on the 'dronification' of contemporary warfare (see, for example, Gregory, 2011; Parks & Kaplan, 2017; Williams, 2011), growing attention is paid to the more-than-military drone as it is 'domesticated' in increasingly varied contexts, spanning civil, commercial and recreational applications (see, for example, Crampton, 2016; Jackman, 2022; Jackman & Brickell, 2022; Kaplan & Miller, 2019; Klauser, 2022, 2022a; Klauser & Pedrozo, 2015, 2017). While scholars have critically traced the 'ascendancy' of the 'good drone' (Jumbert & Sandvik, 2017, p. 1), so too is further attention urged to the 'complex ways in which civilian life is lived with, through and against the drone' (Bradley & Cerella, 2019).

Drone vision has emerged as a central theme across drone geographies. Understanding the drone first and foremost as a visual craft, attention is drawn to the military drone's 'scopic regime' and 'visuality', namely, its 'culturally or techno-culturally mediated ways of seeing' and their (bio)political implications (Grayson & Mawdsley, 2019; Gregory, 2011, p. 190). Building upon this, attention has also been turned to the visual capacities of the more-than-military drone. Approached as an 'eye in the sky', it is argued that the drone's camera opens optic terrains, enabling 'novel' visibilities, the capturing of distinct imagery (Klauser & Pedrozo, 2015), and the rendering visible of 'otherwise hidden perspectives' (Case et al., 2017, p. 75).

While attention to the visual has dominated the drone's study (Agostinho et al., 2020), so too is it increasingly recognised that the drone's capture is not limited to 'visual perception alone' (Zuev & Bratchford, 2020, p. 444). In recognition that drones are both seeing and sensing craft, work has turned attention to the 'more-than-optic' sensors increasingly adorning the drone's frame (Jackman, 2017). Here, attention to the military drone has highlighted that 'before it is a weapon, the drone is a sensor' (Richardson, 2022, p. 3). It demonstrates that, through its 'translation' of person or object to 'target', the sensor plays a central role in the 'violent mediation' of drone warfare (Richardson, 2022, p. 1). Attention to the drone's 'sense-making' has also extended to the technology's more-than-military iterations and applications. Through their outfitting with a diversity of sensors, it is argued that the drone's 'more-than-visual' capacities at once constitute a 'new visuality' that exceeds the 'centrality of the ocular' (Garrett & McCosker, 2017, p. 16; Zuev & Bratchford, 2020, p. 443) and act to 'extend human sight' and 'sense-abilities' in important ways (Fish, 2018).

In parallel, scholars across the social sciences are increasingly mobilising the concept of volume to (re)consider space in three-, rather than two-dimensional terms (Adey, 2013; Elden, 2013; Jackman & Squire, 2021; Weizman, 2002). Through the lens of volume, space is explored not as a surface or area, but in terms of its complex heights and depths. This conceptualisation has precipitated an 'efflorescence' of work attentive to the 'social, political, and cultural reverberations' of 'processes and phenomena that deploy beyond the two-dimensional' (Billé, 2019). Inspired by the contention that we need to 'think volume—think about volume, through volume, with volume' in order to understand the 'complexities of territory today' (Elden, 2013, p. 35), scholars have examined volume across diverse contexts, from aerial and mountainous heights to watery and subterranean depths (see for example Baghel & Nüsser, 2015; Bruun, 2020; Peters & Steinberg, 2019; Slesinger, 2020; Squire & Dodds, 2020). So too has the drone been explored as a technology acting in, capturing, and comprising volume. Following the assertion that drones 'reveal new directions informing the volumetric turn' (Garrett & Anderson, 2018, p. 356), scholars have foregrounded the 'multidirectional spatialities' drones comprise and create (Klauser, 2022, p. 149), and the ways they enable 'complex, visual representations rendering the three-dimensionality of the world comprehensible' (Jensen, 2020, p. 426). As will shortly be unpacked, particular attention therein has been afforded to volumetric policing. Writing in the Swiss context of police drone use in Neuchâtel, Klauser (2021, p. 158) asserts that 'drones mediate novel ways of relating to the air, understanding it, approaching it and acting in relation to it'. Klauser (2022, p. 148) continues that police drones enact an 'aerial geopolitics of security' that relies upon and exerts power in 'three-dimensional ways'. Klauser's (2022) account underscores the utility of both empirically driven drone

scholarship and that attentive to the 'complex voluminosities' of 'mundane micro-spaces' which can be transformed by volumetric technologies (see also Jackman & Brickell, 2022).

While work on volume is increasingly widening to explore a growing diversity of contexts, it has historically fore-grounded military and state-led approaches to and interventions in volume (Jackman & Squire, 2021). This focus is echoed in the critical questions asked of geopolitical volumes, those predominantly centring upon practices and processes of calculation, 'control, enclosure and exclusion' (Squire & Dodds, 2020, p. 4) and resulting in the formation of a 'rhetoric' of volume (Benwell, 2020, p. 93). In recognition that the 'production' of volumetric 'knowledge' is never simply or solely about just the waging of war or claiming of resources (Marston & Himley, 2021, p. 3), scholars have urged both the consideration of a 'more diverse array' of volumetric projects and practices (Harris, 2015, p. 602; see also Pérez & Zurita, 2020), and attention to more 'everyday' accounts of volume (Jackman & Squire, 2021). These impulses are echoed in drone scholarship through calls for greater attention to the 'growing range of non-state actors multiply mobil-ising, experiencing, and subject to the drone' (Jackman & Brickell, 2022, p. 157), and for the formation of a 'specifically domestic drone theory' (Bradley & Cerella, 2019) recognising drones as 'aero-visual techniques of power' (Klauser & Pedrozo, 2015, p. 290) that can at once enact and subvert 'visibilities of control' (Zuev & Bratchford, 2020, p. 442).

In recognition that we can more fully explore the diverse ways in which 'volumes are *lived-in or not* and how they might be reclaimed or made anew' (Adey, 2013, p. 54, emphasis added), this paper foregrounds a snapshot example wherein drones are deployed in sensing for signs of death following a homicide, in order to further interrogate drone sensors as volumetric projects encompassing and demonstrative of diverse sensing sensibilities. While only drawing upon a single example, it asserts that this example both speaks to wider developments in the areas of drone policing and foren-sics (as outlined below), and prompts and opens a reframing of critical questions around and at the intersections of drone sensing volumes. The snapshot example is thus designed to enable the 'telling of a story' (Hitchings & Latham, 2020, p. 394), and to provoke and urge further conversation in this area. In developing and drawing upon this snapshot example, the paper asserts that we are invited to *think volume otherwise*. By this I mean attending to different and experimental drone practice and thereby highlighting distinct drone sensing sensibilities, those which seek and enact different kinds of intervention in volume. In other words, and as is expanded upon in the article's conclusion, by attending to drone sensors as they are more diversely deployed, we are invited to foreground a range of relations and reciprocities between humans and non-humans, those which urge us to revisit existing narrations of drone sensing sensibilities and the vocabularies of volume we use to articulate and narrate them. Undertaking this work offers contribution to both drone geographies and geographies of volume alike. In their exploration of drone vision and sensing, drone geographies predominantly foreground violent instrumentalisations—this article's example seeks to complicate and extend such articulations. In a similar vein, geographies of volume largely foreground violent interventions in volume. By turning to the sensor-laden drone's entanglement of airspace, operator, subterranean graves, landscapes and chemical processes therein alike, this paper presents a drone sensing sensibility seeking an alternative form of instrumentalisation in volume.

## 2 | SNAPSHOT: DRONE SENSING FOR SIGNS OF DEATH

In this paper's snapshot example I turn to an experimental project trialling a sensor-laden drone designed to aid in the detection of the clandestine graves of homicide victims and the deceased bodies dwelling within them. Following the provision of context about the project, I explore it as a case enacting and complicating understandings of drone sensing volumes. While drones are emerging as increasingly popular tools in disaster recovery wherein they are deployed to sense for signs of life in order to rescue and save it, in this example I turn instead to drone sensing for signs of death in the context of homicide policing. This snapshot offers an empirically grounded discussion of drones in and as volume, while also recognising the significance of techno-experiments as both 'a valuable mode of technology development and use' and one informing (imaginations of) 'what might come next' (Sumartojo & Lugli, 2021, p. 13). Crucially, it also acts to demonstrate diverse drone sensing sensibilities, relations in and with volume, and droning that exceeds vocabularies of violent instrumentalisation.

### 2.1 | Police drones and sensing clandestine graves

This section provides context on drone-assisted policing, and the emergent and experimental use of drones in sens-ing clandestine graves. A growing number of police forces globally are deploying, acquiring and testing drones;

both the 'idea and reality of police drones have become normalised in policing circles' (Wall, 2013, p. 36; see also Klauser, 2021). Following that the air is an important volume through which to 'manage' and 'control' populations, the drone has been understood as an iteration of 'technologies of atmospheric policing' therein (Kaplan & Miller, 2019, p. 421). Drones have been deployed as tools across a growing range of policing activities, from surveillance and suspect pursuit, event and crowd monitoring, to traffic accident photography. Considered as more portable, flexible, rapidly-deployable and cost-effective tools (in comparison to helicopters), drones are understood as both 'extra patrolmen in the sky' (Wall, 2013, p. 42) and as introducing distinct 'sporadic and punctual' surveillant capacities (Klauser & Pedrozo, 2015, p. 287). While prompting critical questions around atmospheric governance, privacy, civil rights, and the 'disturbing' of military–civilian boundaries (Kaplan, 2020; Kaplan & Miller, 2019; Wall, 2016), it remains that comparatively little has been written about the growing usage of sensor-laden drones in contemporary policing.

As is echoed in global media coverage of drone-assisted policing, drones equipped with infrared and thermal sensors are increasingly deployed in low-light operations to locate errant individuals (e.g., missing persons or fleeing suspects) and objects (e.g., marijuana growing), functioning through the detection of emitted heat radiation (Jackman, 2017). Here, drone sensing extends, expands and diverges from drone seeing. By way of context, drones both contain and can be equipped with a range of sensors. Internal sensors (such as the accelerometer, gyroscope, inertial measurement unit, barometer, GPS and magnetometer) assist the drone with positioning, altitude, speed and orientation (Khurana, 2018). In order to expand the drone camera's view, drones can also be equipped with additional sensors, including thermal sensors (measuring relative surface temperature), multispectral sensors (collecting 'wavelengths that fall outside the visible spectrum' and measuring 'light energy off objects in the environment'), hyperspectral sensors (collecting data on 'narrow and contiguous wavelength bands' and identifying 'subtle differences in vegetation' and other materials), and LiDAR sensors (laser scanning enabling 3D mapping) (Precisionhawk, n.d.). Through the addition of such sensors, drones exceed their designation as 'eye in the sky' or a 'simple cyclops that flies' and instead become part of a 'more than human sensorial assemblage' (Garrett & McCosker, 2017, p. 16). In thinking with the 'instruments' and 'mobile machines' of emergency response (Adey, 2016, p. 33, 40), so too can we further 'probe' both 'the drone's potential for experimentation' (Garrett & McCosker, 2017, p. 18) and the role and relations of the sense therein. In this vein, growing attention is being paid to the potential of sensor drone assisted-policing in the context of the search for clandestine graves and the bodies dwelling therein.

Clandestine graves refer to grave sites containing buried and hidden human remains not intended to be found. They range in size from 'hand dug graves' with a single victim buried, to larger-scale mass grave sites utilised by violent (repeat) perpetrators (Blau et al., 2018, p. 320). Given the significance of recovering a body (or bodies), both in investigatory, evidentiary and emotional terms (for bereaved families), the detection of clandestine graves is 'pivotal' (Blau et al., 2018, p. 320). While clandestine graves are typically visually discerned through a range of environmental, covering and scavenging 'signs' (Kalacska et al., 2009, p. 159) and/or with the assistance of witness and informant testimony, such practices form part of a wider process of 'geographic profiling'. As Berezowski et al. (2021, p. 1) write in the context of homicide cases, geographic profiling refers to the 'amalgamation of criminological, psychological, and geographical knowledge' with the aim of 'identifying spatial patterns associated with criminal behaviour' in order to 'locate' both the offender and 'the covert body deposition sites of their victim(s)'. Given that ground-based visual detection is both resource intensive and risks the potential 'destruction' of scenes (Murray et al., 2018, p. 45), aerial approaches have been pursued in seeking to identify clandestine graves.

Researchers have interrogated the use of manned aircraft equipped with cameras and sensors, comparing 'simulated' and 'false' graves, and aerially monitoring how these changed over time (Kalacska et al., 2009, p. 165). It was found that while photographs from manned aircraft contained useful 'spatial and contextual' information, data captured by sensors provided additional and particularly pertinent 'information about the surface' (Kalacska et al., 2009, p. 160). Manned aircraft, however, remain costly. As such, researchers are increasingly experimenting with drones as tools that at once enable the searching of wide areas 'in a short amount of time' with 'reduced person power' (Berezowski et al., 2021, p. 6), and are comparatively more affordable and accessible (Murray et al., 2018). Therein, researchers are equipping drones with increasingly diverse sensors—including thermal, infrared, near infrared, hyperspectral, and red-green-blue—each seeking to differently apprehend, make identifiable, and render visible different aspects of the 'environmental fingerprint' left by the act of burial (Murray et al., 2018, p. 50; see also Bodnar et al., 2019). For example, in the case of infrared sensors, experiments have taken place to discern the role of temperature changes in the detection of graves containing animal carcasses. As a body—human or non-human mammal—decomposes, there is a change in body heat per thermogenesis (Bodnar et al., 2019), as well as a change in the 'thermal properties of buried material relative to its surroundings'

(Murray et al., 2018, p. 52). Such factors are being explored as potential signs through which to aid in the detection of clandestine grave sites. While unfolding, such research is understood as 'promising' (Blau et al., 2018, p. 336).

In order to further explore drone sensing in the detection of clandestine graves and the subterranean bodies below, this snapshot now turns to a first-hand example, drawing on semi-structured interviews and correspondence with 'aerial necrosearch specialist' and postgraduate researcher Mike Parsons.[1] These communications focused upon the design process of this unfolding drone experiment, the roles the drone is presently undertaking and is anticipated to undertake. Mike is pursuing his doctorate at the University of Central Lancashire and Mike's research assesses the utility of drone-enabled 'multispectral imaging to detect cadaver decomposition islands (CDI) that form in the vegetation above a burial' site (correspondence 2020; see also Parsons, 2020). Following the decomposition of a body, the 'chemistry of the soil beneath' is altered, resulting in a CDI, namely a 'highly concentrated area of organically rich soil' (Costandi, 2015). When asked about how he came to this interest, Mike describes a context of 'budget cuts for law enforcement' motivating and driving him, with engineering peers, to experiment with sensor-laden drones as tools that might assist police investigations in searching for clandestine graves (correspondence 2020).

Given that 'as a body decomposes' it impacts upon the nutrients in soil, reducing 'the uptake of chlorophyll plants use to perform photosynthesis' and as such 'reducing the overall health of plant-life', Mike was interested in exploring whether a sensor-laden drone could be used as a tool in the identification of a 'presumptive indicator of a CDI' (correspondence 2020; see also Parsons, 2020). To this end, Mike outfitted a consumer drone (Mavic 2 Pro) with both a normalised difference red edge (NDRE) sensor able to provide 'accurate health data' of the plant life 'in the region', and a near-infrared (NIR) sensor enabling the highlighting of 'ground disturbances' (such as digging and dragging; Figures 1 and 2).

In March 2020, Mike began testing the drones. In order to 'operate the scans' he pre-programmed the 'autonomous system' to follow a specific route (correspondence 2020). While noting that it was initially a 'little disconcerting as you are not manually controlling the flight', he proceeds to detail testing the sensor-laden drone over two graves—one of which is 4 months old and contains a 'pig's head and organs', and the other of which is 14 months old and contains a deceased horse (buried by its owner) (correspondence 2020). Mike found that the sensor was able to identify both 'unhealthy' vegetation at the site of the pig's grave—'showing up as a distinct red colouration', and 'healthy' vegetation at the site of the horse's grave—with the sensor's imagery showing up green (correspondence 2020). This difference in colour is due to the 'timescale of the decomposition', given that after around 12 months, the 'CDI becomes rich with nutrients and creates an area that encourages growth, far beyond that of the neighbouring environment' (correspondence 2020). Mike continues that further attention is needed to the dimensions of volume and the impacts of depth—both at the 'standard shallow burial of 2 feet' and at 3 feet, as well as to the conditions of dwelling in volume—that is the impacts of whether victims are 'clothed or unclothed, adults or children' (correspondence 2021).

Mike continues that while the drone is designed to 'locate anomalies' and 'areas of stress within plantlife', it cannot 'definitively say' whether a site is a grave, rather it 'narrows down' a search area which then 'requires further investigation' by a forensics team (correspondence 2020). To this end, Mike has engaged with 'several police forces in the UK' as well as with 'drone manufacturers and training companies, and cadaver dog trainers' in further exploring the project's viability (correspondence 2020). Notably, Mike was also able to field test his drone in the context of two historical homicide investigations, namely the 'Moors murders' perpetrated in the 1960s by Ian Brady and Myra Hindley in and around Manchester (UK), and the murders perpetrated by Fred and Rose West, a UK couple who abducted, assaulted, tortured and murdered at least 12 women over a 20-year period (1960s–1980s). In the case of the 'Moors Murders', Mike looked



**FIGURE 1** Mavic 2 Pro with normalised difference red edge (NDRE) sensor. *Source*: Mike Parsons (permission granted).
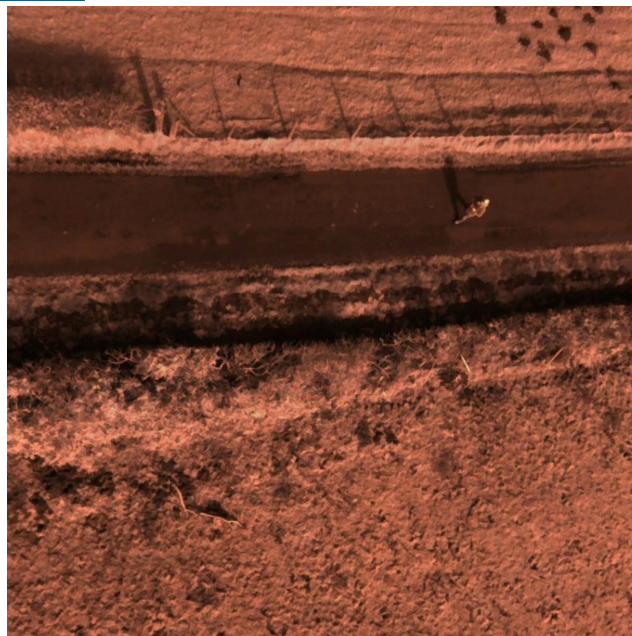
**FIGURE 2**  Near infrared (NIR) image showing cut marks on a grave. *Source*: Mike Parsons (permission granted).

at three areas, designating two as 'natural anomalies' and one as fitting the potential 'characteristics' of a clandestine grave (correspondence 2021), with his drone correctly identifying the grave of victim Robert Killbride (correspondence 2022). In the case of the murders by Fred and Rose West, while Mike's investigations identified 'no new areas', the drone did 'accurately identify the grave locations of two victims', both of which were 'found with NIR imaging, due to differences in reflectivity of turned over soil' (correspondence 2022). Further, working in the context of Fingerpoint field also prompted Mike to encounter and grapple with diverse human interventions in the landscape, such as 'farmers ploughing a field', meaning that 'vegetation was destroyed' (correspondence 2021). Such experiments ultimately encouraged Mike that the 'concept' is 'coming into fruition' (correspondence 2021), an assertion echoed in recent literature which at once identifies a 'critical gap' in forensics literature around 'how burials re-vegetate' over time, and asserts the importance of understanding 'long-term recovery trends' (Rocke & Ruffell, 2022, p. 72, 85).

## 2.2 | Drone sensing sensibilities

In unpacking this snapshot's example, we can engage with literature that has explored the military drone's multi-sensory capture and the relations underpinning it. As we have seen, the military drone is commonly presented as an 'all-seeing eye' pursuing a 'total view', its vision extended 'beyond the visual' and into 'the whole spectrum of the electromagnetic field' (Adey, 2008, p. 1322; see also Weizman, 2002). As Lisa Parks (2014, p. 2518) writes of the sensor-laden military drone, thermal sensors scan for the heat emitted by the bodies of 'targets', correlating 'pixel qualities with temperature values'. This is reinforced in the testimony of drone sensor operators, who powerfully describe watching and working in infrared. Following a drone strike, a (former) sensor operator describes a scene whereby 'the smoke clears' and a man is 'missing his leg above the knee … blood is squirting out' and it looks 'hot' on the screen (Bryant in Power, 2013). Following that the infrared drone 'relates first to an individual's bodily surface and interior: detecting the emissions of the temperature regulation function of the hypothalamus' (Jackman, 2017), the sensor operator continues that he watches on as the blood 'spurts out in the rhythm' of the man's heart before 'he becomes the same colour as the ground' (Bryant, 2017, p. 320; Bryant in Power, 2013). This way of relating to the 'target' is understood as significant because in apprehending in relation to a person's 'heat signature' or 'mere radiation of signs of life', sensor targeted bodies are rendered into 'anonymous heat-emitting entities' or 'indistinct human morphologies' (Parks, 2014, p. 2519; Pugliese, 2011, p. 843). In other words, 'what precedes the destruction of a human body' is the visualising work of sensor technology 'enabling the construction of a targeted human' (Kaufmann, 2017, p. 277). Thus, in their 'hunt for heat' (Parks, 2014), sensors constitute an important aspect in the military drone's 'manhunting' (Wall, 2013, p. 32), sensing for signs of life in order to end it.

While scholars have importantly critiqued both the logics underpinning and the implications of these relations, so too are these relations arguably reimagined and redeployed across increasingly diverse contexts of emergency, that is in 'unforeseen' and/or 'disruptive situations' that pose 'risk to life, health, property or environment' and thus 'demand urgent response' (Kaufmann, 2017, p. 267). These range in scale from 'large-scale emergencies' such as natural disasters, to 'smaller scale' emergencies such as 'missing persons' (Kaufmann, 2017, p. 267). Following that drones are opening the air to 'novel understandings, experiences and actions', so too are they opening the air to increasingly diverse applications (Klauser, 2022a). Illustrative of the wider 'ascendancy' of the so-called 'good drone' (Jumbert & Sandvik, 2017), drones are increasingly repurposed and reimagined from their military roots, instead as crafts for social, economic, political and cultural means. One example of this is the growing use of drones in emergency disaster response. Herein, drones are understood as 'lower cost' and easier use tools for the 'capture of on-demand visuals', as well as enabling the integration of a range of sensors, when compared to the traditional deployment of 'standard spaceborne and airborne platforms' (Daud et al., 2022, p. 31; Kucharczyk & Hugenholtz, 2021a). In recognition of the value of deploying drones in three-dimensional disaster volumes—as 'disaster damage' is itself 'a 3D phenomenon' (Meir, 2015)—drones have been deployed in diverse (post-)disaster applications, including as cameras for mapping, and as thermal and acoustic sensor-laden platforms to locate individuals in remote or inaccessible locations or in low light or nightfall (Soesilo et al., 2016) and to 'identify sound sources' of shouting victims (Banerjee, 2020).

As we saw above, so too are first responders, from police to fire and search and rescue, increasingly deploying drones in the name of increasing 'the safety and effectiveness of their work' (Jumbert & Sandvik, 2017). This includes drone surveillance or monitoring of scenes, searching for missing persons, and 'providing observations at night-time and in smoky and hazy environments' (Kucharczyk & Hugenholtz, 2021b, p. 8). Notably, across these emergency applications, sensor-laden drones seek *signs of life* with the aim of saving, rather than ending, it. While remaining entangled with wider critical questions of 'the expansion, amplification, and intensification of operative logics of legibility and profiling' that surround police drones more widely (Wall, 2016, p. 1123), in such emergency iterations, bodies are alternatively engaged, related to, and 'categorised' as 'vulnerable, in need of being rescued' (Kaufmann, 2017, p. 277).

As such, returning to drones seeking clandestine homicide graves and the victims dwelling therein, I argue that this example's extension of the relational capacities of sensing to save life demonstrates an 'opening' of volume as 'differently exploratory and navigable' (Jackman & Squire, 2021, p. 495). As Kaufmann (2017, p. 289) writes of the drone in the context of 'emergency management', we can reflect further on the drone's implications for emergency 'triage', that is the 'prioritisation' of urgency. Kaufmann (2017, p. 289) asserts that the drone's 'ability to sense, detect and follow bodies contributes to the construction of the body in need'—someone who is 'suffering or wounded' needs to be 'distinguished from those bodies that are not'. This is significant, it is argued, because it demonstrates the 'powerful role' of drones in 'decisions over life and death' both within and beyond the 'context of targeted killings' (Kaufmann, 2017, p. 289). While a powerful reflection of the drone's construction of and interaction with bodies in its midst, this section's snapshot also invites us to think otherwise with the drone's enacting and enabling of 'sensory' volumes (Klauser, 2022a). After all, in seeking the clandestine graves of homicide victims, Mike's sensor-laden drone seeks not 'signs of life', but instead 'signs of death', material 'anomalies' that might mask and mark a body's remains. The drone here seeks not to identify nor detect the heat-emitting body as it wanders or evades, but rather to sense signs of a still, immobile and deceased body in situ, via the changes to and around it. Drone sensing here is about a different kind of 'saving' or 'rescuing'—that is one of a sense of closure. As will shortly be unpacked, Mike describes this work as associated with 'bittersweet' feelings (correspondence 2020), evidencing motives, practices and emotional reactions that demonstrate the diversity of both drone sensing sensibilities and the vocabularies they evoke and that describe them. In further developing this analytic, I turn to (emerging) literature at the intersection of death and volume to further develop an interrogation of drone sensing volumes.

## 2.3 | Sensing deathly volumes

In unpacking what it means to drone sense deathly volumes, I now consider Mike's project as one illustrative of the intersection between the dead body and the techno-sensor in volume, the analysis of which can valuably be extended by bringing the associated geographical literatures of (subterranean) volumes and the dead (body) into further dialogue.

In writing of volume across diverse heights and depths, a 'subterranean turn' has drawn attention to 'drilling down, diving into, traveling through and speculating with underground and underwater domains' (Squire & Dodds, 2020, p. 4). In examination of the 'different strata, layers, scales, and experiences of the subterranean', scholars have foregrounded both the varied practices of 'burrowing, unearthing, immersing, extracting, engineering, detecting, leaking, surveilling, filling, and

demarcating' that 'take place beneath our feet and away from our eyes' (Squire & Dodds, 2020, p. 10, 6), and the diversity of actors that intervene and dwell in subterranean volume. Reflecting the wider work on volume, subterranean spaces are primarily explored as sites and 'sources of conflict and contestation' (Elden, 2013, p. 41), bound and home to diverse practices of extraction, 'exploitation, control, occupation', 'enclosure and exclusion' (Squire & Dodds, 2020, p. 4). Grappling with the 'density' of the subterranean, then, both raises different 'technopolitical problems' (Slesinger, 2020, p. 17) and engenders different practices through which to render undergrounds 'visible (or better sensible) and calculable' (Hawkins, 2020, p. 215).

Recent work exploring that which 'lies underneath and within' the 'topographical surface' (Benwell, 2020, p. 93) has also turned attention to questions of the governance of dead bodies in subterranean volume. In the context of struggle between 'Palestinian campaigners and Israeli authorities' in a Muslim cemetery, Leshom (2015, p. 36), asserts the importance of attending to 'subterranean spatialities' as sites of geopolitical power and 'necropolitics'. In this vein, writing of shifts in the context of 'burial in England during the 19th century' as a result of the 'abolition of the church rate' and 'imposition' of a new burial act, Byron (2022, p. 1) explores both the 'domestic geopolitics of burial space' and the 'political economy of death and burial'. Demonstrating the 'complicated relations and processes that remake and weave meaning into often unseen depths' (Marston & Himley, 2021, p. 1), Byron (2022, p. 4) highlights the enactment of 'new logics in respect of property, security and capacity' as a result of 'forms of volumetric and material governance' of burial. Byron (2022, p. 2, 1) thus argues that we can understand burial volumes as 'ecologies of material, political, social and affective relations exerted across height and depth', turning attention to questions of 'how burial volumes are governed, understood, contested and coexist'.

Thinking with Byron's (2022, p. 1, 2) attention to both 'affective and embodied sensibilities' and the ways 'the material politics of death is intertwined with socio-affective forces' more widely, enables a reflection on Mike's project anew. With his drone, Mike searches out 'surface anomalies'—namely 'details that the human eye would miss' when 'walking past' at ground level but that 'stand out like a beacon in aerial imaging' (correspondence 2020, 2021). These 'anomalies' emerge as a result of entanglements between the surface and subsurface. In searching for these anomalies, Mike's project enacts a form of assessment that while calculative, as it is reliant on the sensor's designation of potential markers to be explored, is not extractive nor mobilised in conflict, but rather seeks to resolve violence. Here, Mike's project reminds us that to sense the subterranean both raises different questions around how we come to know these spaces and render them visible (see Pérez & Zurita, 2020), and can forge new 'knowledges' and practices of 'search' that are at once 'technical, physical, and emotional' (Parr & Fyfe, 2013, p. 617).

In this vein, geographers have more widely focused attention to both 'deathscapes', that is, the 'places associated with death and for the dead' (Maddrell and Sidaway, 2010, in Heng, 2021, p. 219), the lived experiences and 'more-than-representational' dimensions of bereavement (Maddrell, 2016, p. 169), and the different ways in which the 'deceased continue to be present within' and beyond the lives of the bereaved (Maddrell, 2013, p. 505). Therein, work has recognised the significance of 'ambiguity' on practices and experiences of remembrance when a loved one is missing (Kovras & Robins, 2016, p. 41). In recognition of the dead body as a 'political subject' capable of both 'nourishing and haunting the living' (Kovras & Robins, 2016, p. 43), work has examined different 'material forms and practices' that (re)produce the 'bonds' between living and dead (Maddrell, 2013, p. 501, 505). Here, particular attention is paid to 'objects associated with the deceased', such as personal possessions, which may 'become emblematic of the deceased or of their absence' (Maddrell, 2016, p. 180). This has also included explorations of the role of objects and practices, such as photography, in the 'visualisation and understanding' of 'absence in deathscapes' (Heng, 2021, p. 219). Heng (2021, p. 219) asserts that photographs can be understood as 'praxis-moments', namely the practices of individuals to 'inscribe meaning into deathscapes' and 'evoke the feeling of absent individuals'.

So too can we see both objects engaged and bond-making present in the relations between the drone operator, sensor-laden drone, and subterranean homicide victim, in the case of Mike's project. Speaking of 'investigating potential homicide burials' with a drone, Mike describes how the drone's gaze 'almost transports you to the time and place' of the murder (correspondence 2022). Bringing together the drone's aerial view and forensic training, Mike describes both 'seeing' a scene 'in a different light, you understand more, search for more clues', and the ways in which he seeks 'connection' in order to 'identify certain features on survey maps' (correspondence 2022). Mike continues that while such connections can be 'unsettling', this is somewhat 'balanced' by the 'solace that you are a small part of a team that might bring about justice to a victim or closure to a family' (correspondence 2022). Mike continues to describe the 'feeling' of locating a potential clandestine grave as 'bittersweet; on the one hand, you hope that a missing person is found alive and every potential site that comes up as negative means there is still a glimmer of hope, but if a grave is located and a body recovered, there is a sadness but also a relief that you have played a part in the location of the victim' (correspondence 2020). Just as Mike is impacted by those missing, so too does the sensor impact the very same, at once potentially revealing and altering the geographies of death, and impacting the 'multi-layered geographies of living with loss' for the

bereaved (Maddrell, 2016, p. 184). Here, the drone 'entangles' operator and victim, enabling particular forms of 'intimate' relations and 'reciprocities' (Fish, 2022, p. 867, 866). In other words, the dead continue to impact the lives of the living, and the drone's non-human sensor acts to impact the dead.

In thinking further with this reciprocity, one that recognises the multiple agencies at play and the afterlife of the victim's body, so too might we engage feminist work reminding us of the value of diversifying both the actors and relations at the centre of our accounts of geopolitical worlds, relations and volumes alike (Jackman & Brickell, 2022). Feminist geopolitics is instructive in foregrounding both the scale of the body and the site of the everyday. While long-placing attention to the diverse 'bodies at the heart of geopolitics', it has been asserted that engagements with 'materiality' therein were 'implicit' rather than more fully 'developed' (Sharp, 2021, p. 990, 911). To this end, feminist geopolitics has pursued a 'feminist materialism' (Hyndman, 2019, p. 9) that argues that questions of embodiment need not be the 'be all and end all' (Dixon, 2014, p. 147). Rather, we can turn to the sites and 'potential capacities of non-corporeal, or extracorporeal, flesh' (Sharp, 2021, p. 994). In exploring the diverse '"matter" of the geopolitical' (Dixon & Marston, 2011, p. 445), Dixon begins from the 'materials of the body rather than from a human subject' (Smith, 2018, p. 80). Therein, Dixon (2015, p. 85) engages, for example, with bones, to consider how these 'obdurate yet breakable fragments are afforded an "afterlife"'. Reflecting on the political work of bones, Dixon (2015, p. 85), traces their role as evidence of violence, unpacking how they have been variously 'understood, valorised, ignored and recovered in tangible expressions of a lived experience of suffering and trauma'. In thinking with the 'non-corporeal', Dixon's (2015) work at once asserts that the 'afterlife' of the corpse exceeds the 'biological', and that such matter matters in the formation of geopolitical worlds. This materialist trajectory of feminist thought needs not, Sharp (2021, p. 995) asserts, to 'lose a sense of the body as a locus for social justice'. After all, the afterlives of bodily matter such as 'bone fragments' come 'literally to embody the missing for their relatives' and continue to be 'animated and made meaningful' by the very same, as well as by wider 'forensic' communities (Sharp, 2021, p. 998). Thinking with such feminist work enables us to understand Mike's experimental forensics project as one seeking to comprehend one 'way in which bodies and other materialities' come together and are 'caught up in' geopolitical volumes (Sharp, 2021, p. 1005). Exploring Mike's project as such at once recognises and accounts for the materialities and agencies of the dead body in impacting and reshaping its surroundings, recognises these as material evidence of the violence of criminal homicide and the uneven power relations therein, and enables attention to how the (dead) body variously engages with (forensic) volumetric techniques and technologies, including the drone. As is the subject of the article's conclusion, this snapshot also poses further critical questions around the sensibilities and vocabularies associated with and mobilised in discussion of both the drone and volume more widely.

## 3 | CONCLUSION

Building upon the assertion that the 'suddenly pervasive' drone 'straddles a divide in geography' as it is at once an 'important tool for proximal sensing' and a technology with a complex lineage with which to critically engage (Garrett & Anderson, 2018, p. 341), this paper turns to the example of drone sensing volumes in search of clandestine homicide graves as a means to raise and explore questions at this intersection. The article's example urges us to think both 'with' the sub-surface (Squire & Dodds, 2020) and with the role of technological instruments in their rendering visible and knowable. The article's conclusion further unpacks the notion of *thinking volume otherwise*, shifting attention from questions of technological instruments in volume to consider alternative instrumentalisations (Jackman & Squire, 2021).

Drones are commonly designated as 'diagnostic instruments' in contexts of contemporary warfare (Gregory, 2011, p. 188) and emergency response (Adey, 2016) alike. Herein, the use of the term 'instruments' largely remains bound to that of the drone's instrumentalisation as a tool through which to distinguish and determine life and death (Wall, 2016, p. 1126). While not seeking to eschew critical questions of either the 'egis of military need' through which drones emerged (Dodge, 2018, p. 954) nor the logics of 'techno-fixes' more broadly, this paper argues that we can explore techno-interventions in volume in more than instrumental terms (Jackman & Squire, 2021, p. 496).

By recognising the constitutive role of mobile sensors in the formation of 'new kinds of techno-geography' (Ash, 2019, p. 115) and attending to diverse drone sensing sensibilities that seek to resolve, rather than to perpetrate, volumetric violence, we can make space for alternative instrumentalisations, those which prompt wider questions about both 'how it is we know' volumetric spaces (Hawkins, 2020, p. 215) and the diverse motives, sensibilities and relations underscoring these practices. Given that (airspace) volumes can be understood as 'domains and doings, performing different shapes and geometries of insides and outsides' (Adey, 2010, p. 207), we thus can and should tell diverse stories of the ways in which (aerial) instruments—such as sensor-laden drones—variously interact, intervene and transform volume.

While this article presents one example, there are further stories to tell of drone sensing sensibilities. For example, writing of 'drone oceanography', Adam Fish (2022, p. 862, 863) highlights the reciprocal relationships between researchers, instruments (drones) and 'the subjects they investigate'. Fish (2022, p. 862) argues that drones 'improve the collection of biological data' and aid with conservation 'storytelling'. Fish (2022, p. 863) also asserts that the relationships between multiple humans and non-humans therein are 'entangled' and 'mutually affect each other'. Thus, while highlighting the drone's storytelling potential in an 'era marked by existential urgencies', so too is the importance of considering both 'multispecies reciprocities' and 'intimacies' asserted (Fish, 2022, p. 862). While recognising that in Fish's (2022, p. 875) example the bodies of the marine wildlife are 'instrumentalised', so too does Fish remind us of the potential to tell other stories of these relations. In other words, there lies 'political potential' around 'collective action between humans and non-humans' by and through 'thinking techno-geographically' (Ash, 2019, p. 116).

The notion of reciprocity is also echoed in work on sensing more widely. Writing in the context of environmental (citizen) sensing projects, Gabrys (2016) draws attention to the multiple and 'intimate' relations between technical objects, humans and environments alike. In a similar vein, Klimburg-Witjes et al. (2021, p. 24) highlight reciprocity in the sensor's shaping and being 'shaped by the environments in which they are placed' and the phenomena they '(attempt to) render visible'. In the case of drone sensing clandestine grave volumes, this logic of reciprocity is evident in relations between the shifting chemical compositions of the land and the decaying body, and between drone, sensor, operator and the very same. The sensed environment is 'far from passive matter upon which human or non-human sense operates' (Gabrys, 2016, p. 274), rather the sensor and environment are relational and reciprocal.

This is important for two reasons, the first being that Mike's drone does 'more than see the world' (Richardson, 2020), it 'performs and so transforms', 'feeling' and making 'particular problems', in this case homicide, 'matter' (Gabrys, 2016, p. 43, 274). And second, in seeking to detect possible clandestine gravesites, Mike pursues a kind of closure for the victims and their loved ones. Alongside understanding his sensor-laden drone as an agential non-human, 'negotiating and transforming' geopolitical worlds (Dixon & Marston, 2011, p. 445), so too do 'intimate relations' between 'technical objects' (sensors) and their contexts arise (Ash, 2019, p. 115). Importantly, therein we can also identify a different kind of sensibility underpinning the drone's 'rendering knowable' of subterranean 'unknowability' (Forman, 2020, p. 145, 161). Rather than solely or singularly violent, the drone's 'extrasensory visuality' is demonstrative of different sensibilities and impacts (Garrett & McCosker, 2017, p. 13). In other words, in the drone's sensing for signs of death with the aim of resolving, rather than perpetrating violence, Mike's drone enacts a different kind of 'intervention' and relation in volume (Jackman & Squire, 2021). This is significant even as a single example because it prompts wider questions about both the vocabularies we use in accounting for (drone-sensor) volumes and the (sensing) sensibilities underpinning them.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

## ORCID

*Anna Jackman* https://orcid.org/0000-0003-4832-4955

## ENDNOTE

[1] More information about Mike Parsons' work can be found on his LinkedIn page: https://www.linkedin.com/in/mike-parsons-09544 a17a/.

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