Physical Manifestations of Ambiguity
Understanding Drones as Drivers of Ambiguous Influence in the Cyber-Physical Age

by

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Abstract

Operating at the intersection of the cyber and physical domains, the significance and impact of drones in contemporary conflict and security extends far beyond their tangible form and kinetic effects. While often framed as tools of precision and certainty bringing more security to the international arena, this research exposes how drones paradoxically amplify ambiguity within the contemporary landscape of conflict and security. Against the backdrop of a new and complex era of drone use typified by a multiplicity of users, contexts, applications, objectives, and technical capabilities, this thesis exposes how the drone's emerging plurality fosters layers of ambiguity that complicate efforts to clearly delineate the drone's capabilities, purposes, and operators. In doing so, it exposes the drone's capacity to produce a plethora of interpretive challenges that stymie effective responses and create ambiguous conditions that can be exploited by nefarious actors. Through a detailed analysis of the drone's intrinsic and extrinsic properties, this research exposes the depth and plurality of how the drone is *materially assembled* as an ambiguous device. It explores the technology's increasing ubiquity, modification potential, and emerging utility at the nexus of the cyber and physical realms, revealing the drone's active shaping of uncertainty and its facilitation of deniable and deceptive practices in both military and civilian contexts. The thesis develops three innovative concepts that advance our understanding of the drone for international security: the *Liminal Assemblage* – a conceptual tool for understanding the drone's capacity to traverse boundaries, defy categorisations, and generate multiple conflicting narratives about its purpose, capabilities, operator, and origin; *Drone Plasticity* – a novel concept that extends current thinking on the agency of objects in the era of disruptive technologies with the capacity for vast intrinsic, extrinsic, and self-modification; and *Remote Physical Presence* – a reframing of the contemporary drone as an ambiguous actor that inherits and extends the ambiguities of the cyber domain into the physical world, reshaping our understanding of influence, agency and presence in both the physical and digital domains. In examining the role of drones in the production of ambiguity, this thesis contributes to the emerging discourse between security studies and new materialism, bringing to light new ways in which we can observe complex socio-technical systems such as drones shaping international security through the effects they can produce. It advances understandings of how non-human agency plays an active role in the international arena, arguing for a more nuanced consideration of the drone's capacity to give rise to novel modes of influence and effect beyond their initial purposes, which shape how they are used, perceived, responded to, and even designed. While grounded in the context of drones, this framework is applicable to other cyber-physical intermediaries including telepresence robotics, autonomous vehicles, and future developments in synthetic body replicants and advanced humanoid robotics. This research provides an important benchmark for re-conceptualising the influence of complex remote-physical technologies, highlighting the pressing need for better frameworks to address the unique security challenges they pose.

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Author's Declaration

This thesis is the sole work of the author and it has not been submitted in substantially the same form for the award of a higher degree elsewhere.

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1. Introduction

The drone – a cyber-physical system operating across a spectrum of contexts and domains – epitomises the ambiguity characteristic of the contemporary conflict and security landscape. Since the writings of Clausewitz, the condition of uncertainty has remained an enduring feature of discussion in relation to war and conflict. Clausewitz famously described war as "…the realm of uncertainty; three quarters of the factors on which action is based are wrapped in a fog of greater or lesser uncertainty" (Clausewitz 1993, 117), and this idea continues to shape how uncertainty is understood and discussed today. Technology, particularly tools promising to increase situational awareness, have offered a way to overcome some of this uncertainty. In the 21st Century, drone technology is a prime example, often presented as a tool intended to bring more certainty and security through real-time intelligence, pervasive surveillance, and enabling unparalleled levels of precision. Indeed, drones have often been conceptualised as an extension of the human senses, enabling heightened situational awareness and precision at unprecedented levels (Bousquet 2018; Suchman 2020; Strawser 2010). The promise of precision and certainty offered by such remote tools is reflected in their mass adoption among militaries globally (Gettinger 2019).

Yet, these narratives of certainty and precision have not gone unchallenged. Scholars such as Bousquet (2008) and Suchman (2022; 2020) point out the inherent dangers of such technological determinism and challenge the assumption that technological progress can eliminate the "fog" of war. While technologies can provide ways to heighten situational awareness, rather than dispelling the uncertainties they seek to conquer, they introduce new challenges and layers of complexity that undermine the perceived certainty they promise (Bousquet 2008). Much of the literature on drones has focused on the ethical, legal, and strategic problems of these *new tools of certainty* and their alleged precision during the War of Terror (A. Watson 2018; Knowles and Watson 2018; Boyle 2018; Krieg 2018; Coeckelbergh 2013; Gibson 2021). However, we have moved beyond this U.S-centric framework and the landscape of drone use is now far more complex. Today, it involves state actors, non-state actors, diverse missions and objectives, and different technical applications across civilian, security, and strategic contexts. The unprecedented plurality underpinning this new context of drone use raises new questions about the perceived certainty such tools offer. Indeed, while the vast utility of the drone has become clear over the last two decades, a brooding opacity in relation to drone technology has remained insufficiently scrutinised. *Ambiguity* surrounds the drone in multiple forms, presenting disruptive opportunities and creating novel modes of influence and effect that we are only beginning to see flicker into existence.

We can observe drones being deployed in increasingly ambiguous ways across a variety of different contexts, from the disruptive use of drones around Critical National Infrastructure (CNI) causing chaos and confusion, such as the growing number of incidents we see occurring at airports (European Union Aviation Safety Agency 2021), to instances where both state and non-state actors increasingly deny responsibility for drone use and their impacts on the international stage (Lacher 2020). We are seeing the exploitation of the evolving and complex landscape of drone use, and it presents a challenge to our current understandings of this device and its applications. The evolving multiplicity of the drone amplifies ambiguities surrounding their use, from the operator's identity and intent, to the interpretation of their capabilities and functions across contexts. These opacities are introducing new conditions of uncertainty that extend far beyond traditional conflict zones, and we are yet to fully understand the ramifications of this. This thesis sets out to examine this emerging complexity in the development of the drone within security studies, using a New Materialist framework to expose how the drone is both rendered ambiguous and engenders ambiguity in the international arena.

By moving beyond the legal, ethical, and operational discussions that have continued to dominate the drone discourse in the post 9-11 era, this work radically shifts focus to expose and assess the complexities of the strategic ambiguity drones can generate. Through a material-oriented exposition of the drone's inherent properties and attributes, this thesis illuminates for the first time the technology's material assembly as an inherently ambiguous device. Drawing on New Materialism, it illuminates how drones enable plausible deniability, the manipulation of narratives, and the facilitation of political violence on the international stage. In doing so, the work reframes the drone as an actor possessing a unique agentic capacity to shape perceptions, complicate attribution, and generate ambiguity with the capacity to cause confusion, uncertainty, and stymie effective responses. This argument is grounded in a detailed analysis of the drone's intrinsic and extrinsic properties, including its ubiquity, vast modification potential, and inextricable link with the cyber domain; a connection allowing the device to operate as an extension of the cyber domain in the physical realm, while maintaining the ambiguous properties imparted to it through cyberspace. The application of New Materialism throughout this thesis offers new concepts and insights into the drone, revealing it as a technology that is creating ambiguity that can be manipulated in the fog of contemporary conflict, but also beyond it. It demonstrates that we have entered an age where the mass adoption of a technical solution to the fog of war is producing new levels of uncertainty through the ambiguity it conjures, reshaping how uncertainty is both navigated and manipulated in contemporary security contexts.

A central contribution of this research is the introduction of a novel conceptual lens – *the liminal assemblage* – which offers a transformative way of understanding the drone's capacity to blur and traverse conventional boundaries and categorisations. Unlike existing conceptualisations of the drone, the liminal assemblage captures the pluralistic nature of drones as complex socio-technical systems,

illuminating their capacity to conjure a multiplicity of plausible narratives – and thus interpretations – pertaining to their functionality, purpose, operator, and origin. Drone technology continues to evolve, with its purpose, capabilities, and scope of application constantly mutating in ways that exceed our current conceptual frameworks, methods, and defensive capabilities. The liminal assemblage introduced through this research provides a powerful tool for understanding the ambiguities of drone use, highlighting how its properties of ubiquity, plasticity, and cyber-physicality converge to create a plurality of narratives which compound attributional issues and confound cognitive capacities to determine intent, capability, and legitimacy. It reveals how ambiguity manifesting in relation to drone use is not a by-product, but an active phenomenon shaped by the device's inherent material properties and increasingly strategically exploited by actors across various contexts. This lens offers a crucial window into the drone's role in the production of ambiguity within contemporary security and conflict landscapes, allowing us to critically rethink how we understand, train for, and respond to the shifting dynamisms of this contemporary device. By doing so, the research contributes to the emerging dialogue between International Relations and New Materialism, and further enhances the broader drone discourse within Critical Security Studies (CSS).

This thesis further advances the conceptual terrain of New Materialism by introducing the concept of *drone plasticity*. This concept builds on the foundational idea of object agency within the new materialist discourse, providing an original conceptualisation that furthers our understanding of objects that possess the capacity for self-modification through autonomous functionality. Existing conceptualisations of object-agency, such as Law and Singleton's (2005) fluid or fire objects, do not fully capture objects that exhibit vast potential for both intrinsic and extrinsic modification, nor those with the capacity to self-modify. This thesis addresses this gap, providing a critical reframing of the discourse around objects to consider how the vast modification potential of disruptive technologies like drones interacts with, disrupts, and alters traditional notions of object-agency. In doing so, the thesis expands how we can think about agency and objects like drones, which actively exhibit the capacity to dynamically interact with, reciprocally transform, influence, and reshape the security landscapes they inhabit. Further, it provides a crucial lens for the broader study of other emerging and disruptive technologies where autonomy and the ability to self-modify are becoming defining features.

Finally, this work develops the concept of *Remote Physical Presence* which reframes the drone as an ambiguous actor that inherits and amplifies the ambiguities of the cyber domain into the physical world. It highlights that the drone is not simply a remote tool in the hands of an operator, but a cyber-physical entity that itself exerts influence across both its digital and physical dimensions. It emphasises the drone's capacity to 'act' regardless of who may be operating it or why, exposing the devices disruptive potential and challenging ideas about presence and agency in the age of complex

socio-technical, cyber-physical devices. In capturing this, remote physical presence helps elucidate the disruptive influence of the contemporary drone we increasingly see today, where the drone's mere presence alone can cause vast disruption untethered to the operator's identity or intent.

These frameworks collectively advance our understanding of the drone as an inherently ambiguous device whose strategic utility and political implications extend far beyond their tangible form and the impacts of their kinetic effects. This research extends existing understandings of ambiguity in conflict in several important ways, particularly those conceptualised through the grey zone. Through introducing the liminal assemblage and the concept of drone plasticity, this work challenges the assumption that ambiguity is confined to, or produced only by, the ambiguous contexts and environments within which such tools are used. Instead, the work reframes ambiguity as a phenomenon shaped by the very material and technological properties of the devices themselves. This reconceptualisation moves away from the human-centric nature of the grey zone understanding of ambiguity, and towards a framework that incorporates the active role and agency of objects such as drones in the construction, and perpetuation, of ambiguous conditions. Further, in exposing that ambiguity is increasingly transferred by drone technology into domestic and civilian settings, this research highlights that ambiguity is no longer confined to conflict or grey zones, but is becoming pervasive in the broader security landscape. This understanding broadens the conceptual utility of ambiguity beyond the grey zone, illuminating how the strategic use of ambiguity is becoming embedded in global security contexts. In recognising these emerging complexities, this work makes significant contributions to the understanding of both ambiguity and drones within international relations, security studies, and related disciplines, offering an important benchmark for re-conceptualising the influence of complex remote-physical technologies within the international arena.

The remainder of this introductory chapter establishes the conceptual foundations for understanding ambiguity's growing importance to the study of conflict and security in International Relations, particularly in relation to emerging and disruptive technologies like drones. While the Clausewitzian notion of the "fog" of war and the concept of uncertainty have featured heavily in the discourse on war and armed conflict, ambiguity – defined in this work as the condition of being open to multiple interpretations – has received comparatively less consideration. Ambiguity is increasingly a central feature of contemporary conflict environments and dynamics, as exemplified by the rise of grey zone actions, typified by their ambiguous blurring of thresholds. The implications of globalisation and emerging technologies such as drones which enable action-at-a-distance magnify these dynamics through the interpretive distance they create. As the proliferation and evolution of drones continues, their role in relation to ambiguity and uncertainty both in and beyond conflict becoming increasingly significant to understand. Together, the following sections elaborate on this, providing the conceptual groundwork for the thesis and situating ambiguity as a central lens through which we can approach

and analyse the growing complexity drones add to the contemporary conflict and security landscape. The chapter then moves to outline the core research objectives of the thesis before concluding with an outline of the structure and core content of the thesis.

1.1 The Centrality of Ambiguity in Contemporary Conflict

Uncertainty has long been considered an enduring feature of war and conflict. It has been prevalent in writings on war and extensively examined in military theory to understand how uncertainty can shape the conduct of war and the operational environment (Waldman 2010a; Kolenda 2002a; Tarar 2022; Meirowitz and Sartori 2008; Ramsay 2017a). The Clausewitzian notion of uncertainty as a "fog" pervades much of the work considering the uncertainties of war and still serves as an integral anchor for conceptualising the significance of how uncertainty impacts the operational environment (Clausewitz 1993, 117). Opacity can arise surrounding many aspects of war and armed conflict, for example, determining adversarial capability or intent. While uncertainty has received significant scholarly attention, the concept of *ambiguity* – a related but distinct phenomenon – has received less consideration, despite its integral role in shaping conflict dynamics and fuelling uncertainty. Ambiguity and uncertainty are often conflated and used interchangeably, but the two terms are not the same. There is a subtle yet important distinction between them which holds importance throughout this research. It will be briefly outlined here and fully discussed in Chapter 3.

Uncertainty can be defined in several ways depending on different fields of study. This work focuses on two types of uncertainty commonly distinguished in the fields of Risk Analysis, Statistics and Probability – aleatoric (or stochastic) uncertainty and epistemic uncertainty – and outlines how they differ from ambiguity. Aleatoric uncertainty concerns the inability to determine with confidence the *probability of a specific occurrence* (Martinez-Correa 2012). This is related to the inherent variation or randomness within systems or processes, a randomness that is irreducible (Aven et al. 2014, 14). Epistemic uncertainty refers to uncertainty arising due to lack of knowledge about the system or process, and in contrast to aleatoric uncertainty, epistemic uncertainty *can be reduced* by gathering more information or data about the system or process (Hüllermeier and Waegeman 2021, 458). Thus, we can have uncertainty arising from randomness and variation (aleatoric) and uncertainty arising from lack of knowledge or ignorance (epistemic) about a system or process. However, neither concept encompasses issues of *interpretation* around the available data or the meaning of an event once it is observed, and this is where ambiguity is important. Ambiguity is concerned with the quality of something being *open to more than one interpretation* (Oxford English Dictionary 2023b). This quality is described well by Jacqueline Best who points out "the inherent slipperiness of interpretation" at the heart of ambiguity (Best 2008, 355). Ambiguity reflects uncertainty about the meaning and interpretation of information or of an outcome. While uncertainty is the inability to

predict the occurrence of the event (aleatoric) or what events are possible (epistemic), ambiguity is an inability to ascribe a definitive meaning to an event once it has occurred or it has been observed. This distinction is important because probability (linked to both aleatoric and epistemic uncertainty) and interpretation (linked to ambiguity) are different, despite being linked. Within this research, ambiguity is therefore understood as a subset of uncertainty; it is a type of obscurity or opacity arising *specifically* from the characteristic of something being open to more than one interpretation which can, in turn, give rise to, fuel, or exacerbate uncertainty.

While ambiguity is not a new phenomenon in conflict or discussions about it, its importance has become more pronounced as the wider strategic environment has arguably grown in complexity. The term VUCA - introduced by the U.S. military – reflects an environment characterised by its volatility, uncertainty, complexity, and ambiguity. In the VUCA landscape, ambiguity refers to: "a specific type of uncertainty that results from differences in interpretation when contextual clues are insufficient to clarify meaning" (Gerras 2010, 12). It has been observed that the growing opacity of causality, means, motives or methods behind specific events – in synchrony with an ever-expanding actor pool – can fuel ambiguity in the contemporary defence and security environment (Nathan et al. 2016, 18). Indeed, research groups examining the dynamics of contemporary conflict note the growing significance of ambiguity in the discipline as the broader context of conflict increases in complexity through the increasing role of violent non-state actors, the growing hybridity of conflict, unconventional operational environments, and implications of the information age (Changing Character of War Centre 2017). The centrality of ambiguity in contemporary conflict dynamics has become more pronounced in this context. This is notable in relation to the rise of remote forms of warfare and the intensification of grey zone activities in the information age, particularly as tools such as cyber-attacks and drone technology enable new forms of action-at-a-distance which blur traditional thresholds between war, peace, combatants and civilians, while also purposefully obscuring intent, identities, and accountability (Knowles and Watson 2018; Kapusta 2015; Brands 2016). Indeed, the significance of developing a more robust understanding of ambiguity as a phenomenon is more acute against the backdrop and pervasiveness of emerging and disruptive technologies and tools. New means through which ambiguity can be harnessed, exploited or amplified – both in the context of conflict and beyond – are increasingly being adopted. Nowhere is this clearer than in the use of cyber tools, which are now used extensively by a plethora of state and non-state actors to exert influence and will – often anonymously – from a distance. The very nature of cyberspace provides properties through which information landscapes surrounding an event – data about *what* is happening and *who* is making it happen – can be purposefully rendered incomplete. Certain properties of drone technology can also be leveraged in similar ways, rendering aspects of the information landscape around their use incomplete. This is an emerging phenomenon that we are only seeing glimpses of in the international arena, but one that requires critical consideration as the landscape of drone use

becomes more complex and as their capabilities evolve. It is here that we can observe a central paradox, where the increasing integration of information technologies and the techniques it affords aim to enhance precision and control through situational awareness and intelligence, yet at the same time provide the very mechanisms necessary to obscure intent, blur boundaries, and amplify opacities in modern conflict dynamics.

1.1.1 Mapping the Relationship Between Uncertainty and Ambiguity

If we are to fully understand uncertainty and ambiguity, the relationship between the two needs to be explored. From the definitions outlined above, it is clear these phenomena – as both concepts and conditions - are linked, but what is the essence of this relationship?

As stated previously, uncertainty encompasses both aleatoric and epistemic dimensions. Both are quantified through probability – to represent irreducible variation and randomness, or to express confidence or belief respectively (Hüllermeier and Waegeman 2021). Ambiguity in comparison, is concerned with interpretation and perception (Best 2008, 355) and is thus not quantifiable in the same way. However, these concepts are closely linked and it is the nature of this relationship we seek to understand. Is there a causal relationship between them: uncertainty leading to ambiguity or vice-versa? Can ambiguity affect both aleatoric and epistemic uncertainty? Or is ambiguity a concept we can perhaps understand as a phenomenon arising at the peripheries of uncertainty; that is to say, the elements of a situation that *fall outside the remit of calculation,* estimation, or probability? Does ambiguity hinder the calculable dimension of uncertainty, thus enhancing uncertainty further? This is something that is established here.

A useful understanding of ambiguity can be found in Ellsberg's work on uncertainty and risk in decision theory. He describes ambiguity as a condition that sits at the intersection of complete ignorance and calculable risk – the difference between the two coming down to information and one's level of confidence in that information. On the ambiguity of information he writes, it is "a quality depending on the amount, type, reliability and 'unanimity' of information…giving rise to one's degree of 'confidence' in an estimate of relative likelihoods."(Ellsberg 1961, 657). This understanding helps us further delineate the subtle distinction between uncertainty and ambiguity. Uncertainty refers to the lack of confidence in knowing the probability of an event occurring – either through inherent randomness (aleatoric uncertainty) or through lack of information or incomplete information (epistemic uncertainty). Whereas ambiguity arises when the information itself is open to different interpretations or meaning. Uncertainty stems from a lack of information, making it difficult to calculate the probability of an occurrence, whereas ambiguity stems from how information is perceived and interpreted.

Drawing on concepts from nuclear strategy and deterrence, we can further build on Ellsberg's distinction between uncertainty and ambiguity. In writings on ambiguity and nuclear strategy, particularly the work of Thomas Schelling, ambiguity is understood as an *instrument or tool* through which actors can pursue their strategic objectives (Baylis 1995, 5). The work of John Baylis helps to identify a key relationship. Writing about what he refers to as "deliberate ambiguity" in the context of nuclear deterrence, Baylis explains, "[d]eterrence, it is often argued, is enhanced by deliberately creating uncertainty in the adversary's mind" (Baylis 1995, 5). While Baylis is referring here to the work of Schelling and others, his explanation forms an important point of reference from which, when coupled with Schelling's view of ambiguity as a device, we can begin to draw a conclusion about the relationship between ambiguity and uncertainty. Ambiguity can function as a device that can enhance or create uncertainty. Simply put, through actions that elicit multiple interpretations of information (ambiguity), the calculable ability to confidently determine the probability of a specific occurrence is hindered (uncertainty). Furthermore, even when we know with certainty that an event has occurred, ambiguity (multiple interpretations) surrounding the details, framing, or context of that event can elicit opacity, making it difficult to interpret and understand. This elucidates that ambiguity can persists even when uncertainty might be absent; it operates independently, affecting how an event might be understood or interpreted but not whether the event itself certainly occurred.

Table 1. Mapping the relationship between the concepts of uncertainty and ambiguity.

Concept	**Definition**	**Nature**	**Effect**	**Relationship**
Aleatoric Uncertainty	A condition that arises specifically from the inherent variation or randomness within systems or processes.	It is objective and quantifiable in nature as it is an intrinsic property of the system and is therefore not reducible.	This type of uncertainty complicates the capacity to calculate the probability of a specific occurrence, action, or event.	Aleatoric uncertainty can be influenced by ambiguity in terms of how randomness or variation is interpreted.
Epistemic Uncertainty	A condition where there is a lack of information or where knowledge gaps about a system or process exist.	It has both objective and subjective aspects, it is extrinsic (based on knowledge about the system) and is therefore reducible if more knowledge about the system can be gained.	This type of uncertainty limits confidence around accurate predictions because knowledge or information landscapes are incomplete.	Epistemic uncertainty may be amplified by ambiguity as multiple or contrasting interpretations can hinder attempts to remedy any identified knowledge gaps.
Ambiguity	A condition where the information that is available has multiple valid interpretations	It is subjective and interpretive and may sometimes be reducible through	Ambiguity produces multiple possible meanings, explanations	Ambiguity can enhance both aleatoric and epistemic

	that cause different meanings to be ascribed to the data.	clarification but can persist if interpretations differ.	or interpretations of available information.	uncertainty by adding layers of complexity to the information landscape.

1.1.2 Conceptualising Ambiguity

To elaborate on ambiguity as a phenomenon and concept in conflict, it is necessary to understand how it has thus far been conceptualised in relation to the study of conflict. Most prominent in this regard are the concepts of strategic ambiguity – related to the study of nuclear weapons, nuclear war, and deterrence; the notion of ambiguous war – related to the deliberate use of confusing and deceptive tactics that obscure the belligerent's involvement; and the concept of the grey zone – pertaining to the breadth of activities spanning the spectrum of war and peace.

Strategic ambiguity

Strategic ambiguity as a concept is most prominently associated with the works of Thomas Schelling on arms, and John Baylis on nuclear strategy and deterrence (Baylis 1995; Schelling 2008). The concept refers to the establishment of ambiguity in or surrounding a strategy or policy to secure an overarching aim. Drawing on the work of Schelling, Mumford makes a key distinction between "deliberate ambiguity" and "unintentional ambiguity" (Mumford 2020, 3–4). Deliberate ambiguity as it relates to nuclear weapons, enhances nuclear deterrence by creating "certainty of uncertainty" in relation to whether or not the weapons may be used. Unintentional ambiguity in comparison, arises accidentally as a result of disunity or chaos at the strategic level (Mumford 2020, 3). The U.K's Trident nuclear deterrent – in which the location of the submarines at any one time (and which submarine possesses the nuclear weapon) is intentionally kept ambiguous – is a prime example of a policy of deliberate ambiguity. It leverages the multiple plausible interpretations as to the submarine's locations and whether it is carrying a nuclear warhead to make certain that adversaries are uncertain about these pieces of information. Ambiguity in this context is thus purposefully constructed through multiple interpretations and wielded (reaffirming Schelling's understanding of ambiguity as a device) to create uncertainty in the mind of the adversary.

While the concept of strategic ambiguity is useful in helping us understand how ambiguity may be deliberately or inadvertently created, it does not fully inform the conversation on ambiguity in terms of unpacking in detail how these conditions are created. What we can deduce from the dichotomy Baylis makes between deliberate and unintentional ambiguity is that both are equally important for this research going forward. Indeed, the relevance of these concepts extends beyond the context of

nuclear strategy and requires fresh consideration in the context of broader forms of conflict in the contemporary age. We can already note a similar wielding of ambiguity in many other contexts such as the use of cyber, Special Operations Forces, and unmarked soldiers (see section 3.3). Moreover, we are beginning to see both deliberate and unintentional ambiguity arising in new ways as emerging and disruptive technologies introduce novel variations in how ambiguity can manifest – drones being a prime example.

Ambiguous Warfare

Ambiguous warfare is a term that has been in use since the 1980's and which gained renewed relevance following the annexation of Crimea by Russia in 2014. The term has been used to broadly refer to: "situations in which a state or non-state belligerent actor deploys troops and proxies in a deceptive and confusing manner – with the intent of achieving political and military effects while obscuring the belligerent's direct participation" (Connell and Evans 2015, 3). It is a term, however, that lacks significant scholarly development. Acknowledging this ill-defined concept of ambiguous warfare, Christopher Paul highlights the general agreement among thinkers and scholars on the subject of ambiguous warfare as that seeking "…to achieve political or military effects without direct attribution to them, so either through proxy forces, maintaining plausible deniability, or through covert or clandestine activity", further noting that ambiguous warfare can be considered a subset of grey zone warfare (Paul 2016).

The Grey Zone

> Instigators of gray zone conflict prize ambiguity, because it fosters doubt as to precisely what is happening, and who is making it happen.
> - (Brands 2016, 7)

Uncertainty and ambiguity are not unique to conventional war. There are other forms of conflict – those that fall short of war – which encompass these intrinsic features. As established previously, it is the condition of ambiguity rather than uncertainty that will remain the focus of analysis throughout this research – that is, the condition of something being *open to more than one interpretation*. Accordingly, it is here that we turn to the concept of the grey zone – a concept that has the feature of ambiguity at its heart. The term Grey Zone Conflict has accrued numerous definitions, with much debate as to what forms of conflict fall within this category (Brands 2016; Kapusta 2015; Votel et al. 2016a; 2016b; Nathan et al. 2016; Hoffman 2016a). This 'zone' has been fittingly described as "…the awkward and uncomfortable space between traditional conceptions of war and peace" (Nathan et al. 2016, xiii). Hoffman highlights a spectrum of conflict animating the space between the dichotomy of peace and war (see Figure 1) (Hoffman 2016a, 29). He defines conflict arising in the grey zone as:

"…deliberate multidimensional activities by a state actor just below the threshold of aggressive use of military forces" (Hoffman 2016a, 26).

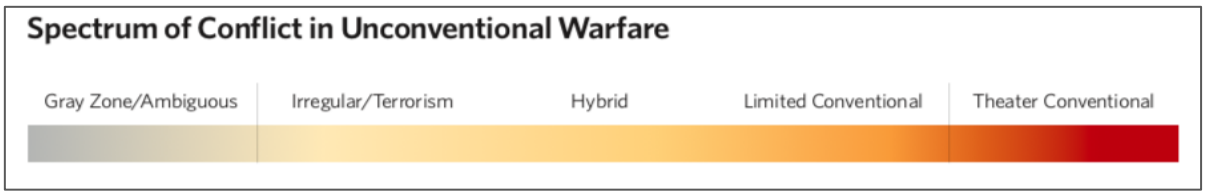

Figure 1. Frank Hoffman's Spectrum of Conflict in Unconventional Warfare. Reproduced from Hoffman, F. (2016).

While there exists debate over the concept of the grey zone concept and its utility, a recurring characteristic widely agreed upon by many is *ambiguity* (Nathan et al. 2016; Brands 2016; Wirtz 2017; Kapusta 2015; Hwang 2021; G. Hughes 2023). Indeed, Brands points out the "inherently ambiguous" nature of grey zone challenges (Brands 2016). Further, Kapusta, highlights several aspects of grey zone conflicts that are shrouded in ambiguity, including the nature of the conflict itself, the opacity of the actors involved, and uncertainty about applicable policy and legal frameworks (Kapusta 2015, 20). Votel et al (2016a, 102), further highlight the ambiguous nature of the grey zone by emphasising its often-covert features, characterising grey zone conflicts as those involving clandestine and covert operations, often with low-visibility and a small foot-print. Beyond forming a useful framework within which to categorise and analyse certain types of covert, or ambiguous, action that fall below the threshold of military retaliation, the grey zone concept is useful for the research being undertaken here for its emphasis on thresholds and intersections. Freier et al (2016, 3), provide a useful point of reference to illustrate, highlighting that grey zone activities lie at certain intersections:

> "between doctrinaire conceptions of war and peace, between legitimate and illegitimate motives and methods, between universal and conditional norms, between order and anarchy, and finally, between traditional and irregular or unconventional means"

It is precisely these intersections that provide the space for actors to animate and exploit. To follow Hoffman, where grey zone conflicts are "…aimed at a gap in our intellectual preparation of the battlespace…"(Hoffman 2016a, 20), they are also aimed at the gaps that lie between these crucial intersections. While important to recognise that the occurrence of grey zone activity is not new in itself (Brands 2016, 5), akin to the character of war changing as new actors and means enable it to be waged differently, so too is the *character* of grey zone challenges shifting. Indeed, globalisation as a driving force of grey zone challenges has been acknowledged among key thinkers and scholars in this area of study (Kapusta 2015, 22). As emerging technologies are more widely embraced, this trend is continuing further, with new forms of action – or influence – at a distance coming into being. Take for example the growing embrace by both state and non-state actors of the cyber domain to interfere or

exert influence at a distance. A primary feature of cyberspace is the certain level of anonymity it can afford; enabling actors to evade culpability (Libicki 2011). Developments in technology are expanding the horizons of covert, ambiguous, and short-of-war actions typified by those occurring in the grey zone. The ubiquity of certain tools enabling *action-at-a-distance* – such as drones – not only thrive amid the ambiguities of grey zones, but simultaneously contribute to an amplification of ambiguity by providing mechanisms through which attribution, intent, and accountability can be complicated. This interplay between emerging technologies and ambiguity, what it may enable, and what it represents more broadly, are underexplored and yet crucial for our understanding of contemporary security going forward.

1.2 Remote Warfare and the Ambiguities of Distance

Distance and conflict are intimately entwined. Just as technological progress has sought to eliminate uncertainty in conflict, it has also sought to conquer the challenge of distance. From melee weapons to the machine gun, the technological advancement of weaponry has aimed to impose a crucial distance between the wielder and their opponent to enhance safety. Simultaneously, technology has sought to overcome the constraints posed by distance, with advancements such as cruise missiles and drone technology allowing actors to reach far beyond conventional spatial boundaries. We can thus observe a dichotomy at the heart of the relationship between distance and conflict. Derek Gregory encapsulates this dualism well, specifically in relation to the use of drones in conflict: "[t]he death *of* distance enables death *from* a distance" (D. Gregory 2011a, 192). Improvements in communication have facilitated the ability for the soldier to be at once disconnected (physically) and connected (virtually) to their commanders. Such distance not only relates to boots on the ground but also to vehicles and importantly, weapon systems. Technology today has enabled the stretching of geography, communications, and logistics, to such an extent that a sophisticated modern military can cause devastating effect thousands of miles away from where they are based. Digitally sophisticated actors can, to borrow from Der Derian, bring "there here in near-real time" (Der Derian 2000, 772). This situation has been notably conceptualised as a "compression of time-space" enabled by technological progression (D. Gregory 2011a, 192; Harvey 2020). It is precisely this compression of time and space through technology that has enabled the spatial extension of violence across the globe, as much work within the field of political geography elucidates in the context of the contemporary drone (D. Gregory 2011b; 2011a; Ian G R Shaw 2017; Ian, G. R. Shaw 2016). The conquering of distance through technology has facilitated the ability for actors to disperse their activities in ways inconceivable previously. This technological augmentation has enabled various forms of covert and clandestine action; bringing about new means for it to be carried out and new opportunities for influence and intervention. Various terms have come to exist seeking to explain or encapsulate such activities, some of which include remote warfare, shadow warfare, and surrogate warfare (Niva

2013a; Krieg and Rickli 2018; 2019; Adelman and Kieran 2020; McDonald 2021; Rauta 2021). The concept that has become most prominent in this regard is Remote Warfare.

Remote warfare refers to approaches that enable military interventions to take place without the presence of many troops on the ground (Knowles and Watson 2018, 4). This type of warfare encompasses a broad range of activities, specifically those occurring at a distance or in ways less visible than traditional methods (Krieg 2018). Remote warfare encompasses technologically 'remote' forms of exerting influence or effect from a distance, such as drone strikes (Krieg 2018, 5). However, it also encompasses a broader set of tools and techniques which place an intrinsic *distance* between a target and those conducting the operation, including the use of Special Operations Forces (SOF), private military contractors (PMCs), and intelligence agencies (Knowles and Watson 2018). The shift towards increasingly remote forms of warfare is underpinned by several advantages. Of note here is the distance placed between actor and actions, and the crucial *deniability* this can afford an actor (Krieg 2018, 11). While remote forms of warfare offer certain advantages to those using them, notable research highlights the intrinsic challenges arising from remote warfare, including legal issues pertaining to attribution, and ethical issues around the lack of democratic accountability in the conduct of warfare from afar (Riemann and Rossi 2021, 83; Chamayou 2015; Benjamin 2013). These issues are tightly bound with distance. The desire to *overcome* distance and the desire to *create* distance through remote means has introduced new dimensions of separation – spatial, moral, operational, and interpretive, reshaping how distance is used as a tool of warfare and blurring lines of accountability, intent, and responsibility. It is within this context that distance introduces ambiguities that complicate traditional conflict dynamics.

The use of drones in remote conflict exemplifies this paradox of simultaneously overcoming and creating distance. These tools are both remote in the technological sense that they are operated from a distance, and remote in a strategic sense in relation to the *strategic distance* afforded by the critical distance placed between the operator of a system and its effects on the ground (Knowles and Watson 2018, 3). They enable precision actions from a distance while creating moral, operational, and interpretive separations that are ambiguous and hold the potential to exacerbate or amplify uncertainties. The delivery of remote kinetic effects through strike-capable drones from a Ground Control Station (GCS) thousands of miles away from the active kill zone has been a point of contention and ongoing debate in relation to the use of remotely piloted aircraft in war and armed conflict (Strawser 2013; 2010; D. Brunstetter and Braun 2011a; Emery and Brunstetter 2015a; A. C. Orr 2011; Ian, G. R. Shaw and Akhter 2012; Benjamin 2013; Chamayou 2015; Boyle 2018; Rosén 2014; Warrior 2015; Guthrie 2022). These discussions have dominated the discourse on drone use in conflict and continue to do so. While the conversation is certainly seeing shifts to encompass the technological advancement of drones, particularly in relation to artificial intelligence (AI), discussions

often remain tethered to legal and ethical dimensions (Amoore and Raley 2016; Suchman 2020; Wilcox 2016; Lele 2019). These discussions have been pivotal in developing our understandings around the use of drones in lethal action. Underdeveloped in these discussions, however, is how the integration of distance in contemporary conflict – particularly in relation the drone – alters the dynamics of ambiguity in conflict. The compression of time and space that technologies such as drones afford also brings with it an amplification of ambiguity. The separation – or dislocation – between actor and target introduces layers of ambiguity regarding drone operators, objectives, and intentions yet to be fully elucidated. Simultaneously, the landscape of drone use has shifted radically, challenging us to move beyond the traditional moral and legal debates often constrained by the U.S.-centric ways in which this technology has been used, and to examine how the challenges of remote action and the ambiguities it gives rise to translate across these new and diverse domains of drone use.

1.3 The New Drone Age: Evolving Identities and Emerging Ambiguities

Drone technology is no longer solely the realm of sophisticated militaries. Over the last decade, the number of actors in the international system with access to drone technology has risen sharply, introducing a complex landscape of contemporary drone use comprising military, commercial, and consumer drones (Gettinger 2019). The drone of today is ubiquitous, accessible, and flexible in application to a plethora of both state and non-state actors (Chávez and Swed 2021; Fuhrmann and Horowitz 2017). Two main trends have been driving this change. First, the advent of consumer drone technology, which has been embraced for a vast range of both civilian and military uses (PricewaterhouseCoopers 2016; Jackman 2019; Chávez and Swed 2021). Second, the growing proliferation of military drones over the last decade (see Figure 2 overleaf), which has seen more than 95 states add drones to their arsenals, 40 of which include the possession of armed Medium-Altitude Long-Endurance (MALE) drones (Gettinger 2019; Drone Wars 2024).

Both trends have allowed a wider range of actors to gain easier access to an aerial capability (Hastings-Dunn and Wyatt 2018). This change has marked shifts in how we are seeing drones utilised on the international stage, and for what purposes. While the post-9/11 era of drone use was dominated by military targeted killing practices, contemporary drone use is much more varied – from the creeping use of military drones for domestic security purposes like border surveillance (Koslowski and Schulzke 2018) to the use of consumer drones by non-state actors for both intelligence, surveillance and reconnaissance (ISR), and lethal purposes through modification (Chavez and Swed 2020; Chávez and Swed 2021; Rogers 2019b; Plaw and Santoro 2017; Abbott, Clarke, and Hickie 2016).

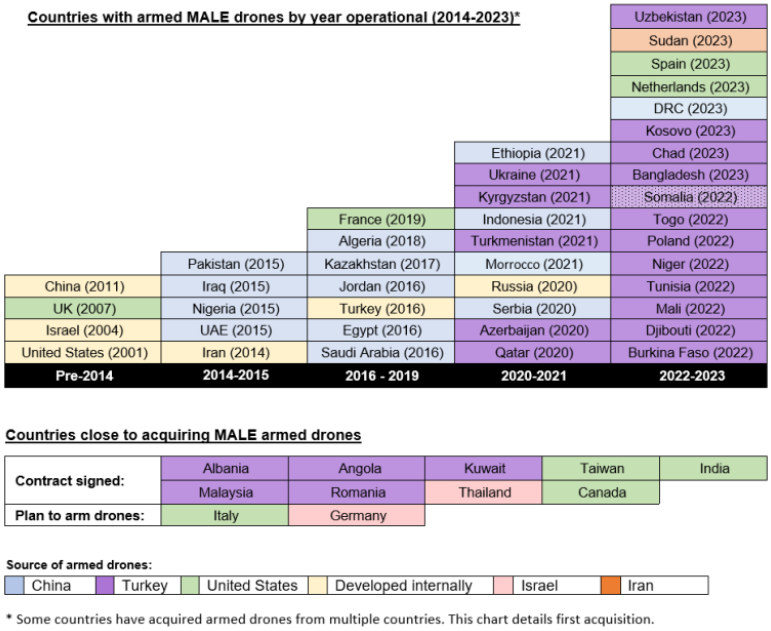

Figure 2. Countries possessing armed MALE Drones 2014-2023. Diagram Source: Drone Wars UK.

Furthermore, we can observe a significant intensification in the use of drones for kinetic effect beyond targeted killing in conflicts over the last five years. The ongoing war between Russia and Ukraine has seen drones of various kinds – military grade drones, off-the-shelf consumer drones, and home-made drones – become a hallmark of the war (Thompson 2024). Ill-equipped to confront Russian-backed separatists, Ukrainian forces turned to hobbyist aircraft enthusiasts, crowdfunded volunteer groups and commercial companies to assist in the development of an Unmanned Aerial System (UAS) capability able to take on Russia (Borys 2015). This trend has continued to the present day, where the use of homemade and DIY drones to support Ukraine's war effort has become the norm since Russia's aggressive invasion of Ukraine in 2022 (Hambling 2022; Pettyjohn 2024; BBC News 2022). Drones played a similarly central role in the second Nagorno-Karabakh War between Armenia and Azerbaijan in 2020, with drones seen as playing a crucial role in Azerbaijan's victory (Shaikh and Rumbaugh 2020).

The contemporary drone – whether the platform is military or civilian in nature – harbours many identities. Despite the growing abundance of this technology, understandings of its implications in relation to security and conflict remain incomplete. Part of this deficit is tightly coupled with two trends: a drone discourse that has been largely dominated by drone use for targeted killing and its ethical, and legal implications; and the drone's continual evolution both in terms of its development, modifiability, and practices of use. This continual evolution is seeing new challenges and opportunities emerge in relation to how drones can be employed and the effects they can generate *beyond* kinetic strike capabilities and targeted killing practices. We are beginning to see the use of drones in ways that challenge our conventional understandings of their typical uses. For example,

drones are being used today in ways that can cause severe disruption and chaos, even absent a lethal payload. Disruptive drone presence at airports and around other CNI has been evident in multiple incidents occurring over recent years (Hambling 2020b; European Union Aviation Safety Agency 2021). What makes these instances so noteworthy is the persistent anonymity that can surround such drone usage, and the disruptive impact their mere *presence* can have on shaping events or responses to those events. The Gatwick Drone incident of 2018 is notable in this regard (BBC News 2018a). Inabilities to determine the drone's operator, or the purpose and intent connected to the drone's presence caused prolonged disruption at a major piece of the U.K's CNI, hindering an effective response (College of Policing 2019). The implications of this kind of phenomenon – where the drone's remote physical presence holds the capacity to cause influence and effect of such dramatic proportions – is not fully understood. Gaps in our understanding of the drone and its implications for security and conflict are further reflected in persistent ambiguities surrounding drone incidents such as the denial of responsibility for drone use both within and outside of the conventional realms of conflict. We continue to see examples of both state and non-state actors denying drone use and their impacts on the international stage. This is a deeply political issue, with the manipulation of narratives challenging traditional frameworks of accountability. Furthermore, attributional challenges often elicit unclear or delayed responses to drone activity as indeterminacy and speculation carve a path for political manoeuvrability and plausible deniability (UAS Vision 2015; Chabin 2013; A. Khan 2020; Lacher 2020; Al Jazeera 2019; Hubbard, Karasz, and Reed 2019; Novikov 2024; Shukla et al. 2023). While the attribution problem related to drones has been acknowledged, especially in relation to the technology's proliferation, it has been insufficiently explored (Boyle et al. 2017; Milan and Tabrizi 2020).

These issues are complex, intertwined, and pose many challenges going forward for our understandings of contemporary conflict and remote physical technologies. Yet, the intricacies of deniability and, indeed, ambiguity, in relation to the use of drones has thus far remained significantly understudied. It is within this context that the true nature of what at first seems a simplistic device – the drone - can be illuminated. This research thus seeks to interrogate how remote physical presence, as presently exemplified by the drone, is *interacting* with the phenomenon of ambiguity as it relates to conflict in new and interesting ways. The significance of these interactions is yet to be fully realised or elucidated both in practice and in intellectual endeavours. This is an important analytical oversight that this project begins to address.

Gaps in our understanding of drone technology are evident, particularly as the evolving nature of drones continues to outpace existing regulatory frameworks. The increasingly accessible nature of drone technology has led to challenges in previously unregulated areas and near sensitive sites which complicates both domestic and international norms around drone use. The use of drones in deniable

ways by both state and non-state actors further highlights the crucial deficiency of our current approach to, and understanding of, drone use. It is clear that we still do not fully understand the implications of the drone in its current – and various – forms. Yet the drone is rapidly changing. This technology is not only transforming as an object, or in the ways it can be used, but as a concept. The very notion of the 'drone' itself is fragmenting as science and technology drive it beyond today's conceptualisations. The above identified problems will only become more complex as drone technology drives forward, enabling new forms and functions. Research into these knowledge gaps is imperative and timely. Contemporary thinking on drones needs to move forward to consider the new disruptive challenges emerging across the entire spectrum of conflict as remote-physical technologies like drones radically shift to new forms and uses; enabling novel modes of influence and effect. If we are to keep pace with transformations in the unmanned domain, we must strive to broaden our conceptual understandings of this fast-paced and non-static object. In light of the observation that drone technology is continuously shifting through various scientific and technological advances and coupled with the ambiguous challenges we already face in relation to remote technologies and the ambiguous contexts in which they often operate, we are faced with an emerging situation in which the ability to fully comprehend the implications of such a rapidly shifting object is becoming more difficult. It is therefore imperative to seek to illuminate now, the existing challenges of ambiguity in relation to this complex socio-technical system and its use within conflict if we are to be in a strong position to understand how such challenges may evolve going forward.

1.4 Research Objectives

Investigating the phenomenon of ambiguity as it pertains to the drone necessitates the consideration of several interconnecting factors. To allow for this relationship to be meaningfully explored, this thesis is guided by the following overarching research objectives:

1. To explore how ambiguity relates to drone use, and to understand what role the material and relational capacities of drones might play in creating, mediating, or amplifying ambiguity.
2. To analyse how the evolving nature of drone technology is reconfiguring the form, function, and practices of drones and their use, and how these changes interact with ambiguity.
3. To investigate how the cyber-physical properties of drones interact with ambiguity, and how these entanglements may amplify ambiguity in security and conflict settings.

Ambiguity is a central yet underexplored challenge, objective 1 aligns with the need to establish a foundational understanding of this phenomenon as it pertains to the drone, building an evidence base for ascertaining its occurrence, relevance, and significance. An initial mapping of the ways in which we can observe ambiguity arising in relation to the use of drones seeks to provide an important baseline understanding of the phenomenon and its various dynamics at the outset of this research.

Objective 2 aligns with the need to understand ambiguity against the backdrop of the drone's rapid evolution and transformation. The drone is highly versatile, continuously being adapted to new applications, and undergoing continuous shifts in both capability and form as science, technology, and unexpected innovation drive it to new heights and unexpected uses. While some advancements offer exciting possibilities for the future of drones, they also add further complexity to the landscape of drone use by multiplying the possibilities and various 'identities' that exist around drone use across both the civilian and military realms. This highlights the need to investigate how technological advancements may facilitate new forms of ambiguity or frustrate existing ambiguities. Finally, objective 3 aligns with the necessity of understanding the drone's unique complexity as a socio-technical system operating at the intersection of the physical and cyber domains. Drones function within diverse contexts and their use spans multiple applications across divergent operational environments, requiring a deeper knowledge of how these dynamics interact with, or shape the emergence of ambiguity.

Collectively, these objectives provide a framework for meaningfully investigating the relationship between drones and the phenomenon of ambiguity. They strive to broaden our understanding of drones beyond their functional roles and kinetic effects, to provide critical insights into their evolving implications within security and conflict settings. Moreover, as one of the first technologies in the lineage of kinetic and modular cyber-physical systems gaining global ubiquity, these lines of inquiry, while coalescing around the exemplar of the drone, provide a foundation for analysis for the evolution of other such systems going forward.

1.5 Thesis Content

This thesis consists of eight chapters which cumulatively fulfil the overarching research objectives outlined above. It takes the reader on a journey from external perceptions of ambiguity arising in relation to drone technology, to an intricate exposition of the extrinsic and intrinsic properties inherently giving rise to this ambiguity in multifaceted ways. To do so, the research employs a systematic approach, using thematic analysis to identify patterns across the collected data. These findings are in turn interpreted and analysed through a material-oriented lens, drawing on new materialist thinking to expose and explore the relationships, dynamics, and affordances at play between the drone's properties, attributes, uses, and the phenomenon of ambiguity. Ultimately, these findings are drawn together and inform the development of a new conceptual lens within this work – the liminal assemblage – to assist our understanding of the drone's plurality and its capacity to conjure multiple plausible narratives pertaining to its functionality, purpose, operator, and origin. This lens offers a novel approach to analysing and understanding how remote physical technologies such as drones lend themselves to the exploitation of ambiguity by nefarious actors, which can – as we

continue to see on the international stage – be used to cause disruption, evade the burden of proof, and leverage plausible deniability to stymie effective responses to drone use. This section outlines the core content and structure of the thesis.

Following this introduction, Chapter 2 presents a thematic literature review of key areas identified as central to fulfilling the research aims. First, the review attends to the concept of ambiguity in international relations, revealing its exploration in the discipline as limited both in the broader context, and in the context of drone technology. While scholars have made initial valuable contributions in *acknowledging* ambiguity pertaining to the drone in some forms, these contributions narrowly address or explore the issue, neglecting any exploration of the broader factors and attributes contributing to the challenge. The review then moves to explore the nascent but growing discourse around drone evolution. Understanding the evolving nature of drone technology is essential for keeping pace with a fast-changing technological landscape and anticipating unexpected uses and challenges coming from these changes. While there is a notable push by some scholars to pay more attention to the modifiability and versatility of the drone, including the attributes influencing their adoption by non-actors, these areas have not been thoroughly addressed or explored in the existing literature. The review then shifts to critical security perspectives, exploring work which recognises the potential for drones to produce unintended effects. It reveals avenues of inquiry around agency and the drone's capacity to *create*, *enable*, or *produce* certain effects or conditions which remain underexplored in security studies and wider international relations scholarship. The review underscores the centrality of addressing these lapses against the backdrop of an increasingly complex landscape of drone use. Bringing these areas into dialogue positions us to better explore and understand how the drone's evolving nature in form, function, and context of use interacts with the phenomenon of ambiguity, producing effects beyond those for which they were intended.

Chapter 3 details the methodology guiding the research design and approach. It focuses first on its qualitative, inductive approach, outlining the Reflexive Thematic Analysis (hereafter TA) the research employs to systematically analyse existing data to identify patterns relating to drones and ambiguity. The chapter goes on to explain how New Materialism informs the analysis and interpretation of the findings. Importantly, it highlights the value of an approach that integrates TA with new materialism, offering a way to better understand the material and relational dynamics that shape ambiguity in relation to drone use. It further includes discussion of data collection challenges, ethical considerations, and limitations of the study.

In the first of three core research chapters of this thesis, Chapter 4 maps the ways in which we can observe the phenomenon of ambiguity manifesting in relation to drone use. Through thematic analysis of existing data, including scholarly work, reports, and grey literature, it attends to research objective

1 and provides a foundational mapping of ambiguity and drone use. This initial phase of the research identifies three predominant themes: ambiguity arising in relation to operator identity; ambiguity of purpose and capability; and legal ambiguities arising from a lack of common regulatory frameworks. These themes are elucidated through examples and discussion, exposing the ways in which the remote and adaptable nature of the drone complicates interpretation around its use. The chapter further identifies two secondary themes pertaining to ambiguity and the drone: deniability surrounding drone use and the increasing ubiquity of the drone across multiple contexts. The subsequent analysis conceptualises and elucidates the cyclical relationship between the drone's ubiquity, its role in compounding the ambiguities identified in the main themes, and the deniability this facilitates. The chapter concludes by conceptualising the drone as a liminal system, which captures the device's existence at the threshold or boundary of multiple uses, users, functions, and capabilities.

Having established several key areas where we can observe the phenomenon of ambiguity in the context of drone use, Chapter 5 builds on previous discussions regarding ambiguity of capability and purpose, moving specifically to explore the underlying material properties that afford, enable or facilitate this extensive versatility. It does this in the context of the evolving and adaptable nature of the contemporary drone, attending to research objective 2 by exploring how these developments interact with the phenomenon of ambiguity. It identifies four primary themes: the drone's physical mutability, including its amenability to ad-hoc repurposing and its increasing modularity by design; advances in drone morphing technology and material production allowing for increasing flexibility of application; digital modification through software customisation facilitating new levels of third party alteration; and increasing autonomy introducing aspects of self-determinism including the capacity in some cases for the drone to modify aspects of itself. Through examples, these themes ultimately reveal the technology's vast capacity for both physical and digital transformation across both the extrinsic and intrinsic dimensions, emphasising its inherently changeable nature. From these findings, the chapter introduces the novel concept of Drone Plasticity to capture this device's capacity for multifaceted change. This lens provides a mechanism for understanding how the drone's modification potential shapes ambiguity pertaining to its functions, capabilities, and roles. It further offers an important extension to existing concepts of object-agency, providing a conceptualisation that takes into account the extrinsic and intrinsic capacity for objects to both be altered, and to alter themselves through autonomous functionality.

The drone represents a collision of the digital and physical realms. Chapter 6 turns to specifically interrogate the drone's cyber foundation to understand its interaction with the phenomenon of ambiguity. It further expands on the challenges of anonymity initially discussed in Chapter 4, building a more detailed understanding of the various ways through which such anonymity is made possible, enabled, or facilitated through the drone's existence at the cyber-physical nexus. In doing so, this

chapter addresses research objective 3 and identifies three central themes: the intrinsic invisibilities imparted to the drone through its cyber roots including digital traceability challenges and algorithmic opacities; the drone's transcendence of virtual and physical boundaries; and its dual materiality as both cyber and physical attack surface and vector. Through examples, it demonstrates how the drone amplifies the ambiguities characteristic of cyberspace and extends them into the physical realm, challenging traditional boundaries and categorisations across the physical and digital. Ultimately, the chapter introduces the concept of *Remote Physical Presence* – a conceptualisation that encapsulates the drone's capacity to exert influence across both the cyber and physical domains, in turn shaping and reshaping perceptions of influence, presence, and agency in both the digital and physical domains.

Drawing together key findings from across chapters 4-6, Chapter 7 explores how the drone's ubiquity, plasticity, and cyber-physicality coalesce and interact to produce ambiguity around the drone in both conflict and security settings. It draws on assemblage thinking to reconceptualise the contemporary drone as a liminal assemblage; a dynamic grouping of the material properties exposed through this work, which allow the drone to exist at the intersection of various uses, contexts, forms and functions. This chapter develops the liminal assemblage as an innovative conceptual tool that can aid in our understanding of ambiguity and its production through remote technologies such as drones. It offers a fresh perspective on the drone's unique capacity to blur and transcend conventional boundaries, capturing their pluralistic nature and allowing us to examine for the first time how different attributes of the drone converge to create overlapping narratives that generate ambiguity surrounding their use. It further draws on Bennett's (2010) concept of 'thing-power' to elucidate how the drone as a liminal assemblage possesses a unique agency that extends beyond its mere utility, to its active role in the shaping of perceptions, events, and the wider political landscape through its production of ambiguity and its facilitation of deceptive practices. The conceptual lens of the liminal assemblage deepens our understanding of how drones shape ambiguity in modern security and conflict, whilst also encouraging a critical rethinking of how we approach, prepare for, and respond to the ambiguous challenges posed by remote-physical technologies such as drones.

Chapter 8 concludes this thesis by offering an evaluation of the method, the core findings, and their implications for theory and practice. It first highlights the effectiveness of the integration of thematic analysis and new materialism for studies within International Relations, illustrating its efficacy for exploring complex adaptive systems such as drones and their capacity to generate phenomena beyond their typical purposes. Notably, this union allowed for a deep exploration that moved from external manifestations of ambiguity through to the intrinsic facets of the device playing a role in the phenomenon. In doing so, this work advances the drone discourse in Security Studies and International Relations, exposing the depth and plurality of the drone's material assembly as an

ambiguous device, and bringing into sharp focus the drone's agentic capacity to shape perceptions, dynamics, actions, and outcomes on the international stage. The liminal assemblage conceptualisation developed through this work provides a unique way to understand cyber-physical technologies that blur boundaries and the plurality of narratives they can conjure, highlighting its applicability to other emerging and disruptive technologies beyond the drone. The research further extends thinking within the broader new materialisms through its introduction of *drone plasticity*, a concept capturing the capacity for cyber-physical objects to self-modify in the age of increasing autonomy and how this impacts our thinking around such objects and their implications for conflict and security. In providing new insights into how the drone's latent ambiguity can be strategically and politically exploited, the research broadens the conceptual utility of ambiguity beyond the grey zone, illuminating how the strategic use of ambiguity is becoming embedded in global security contexts as dual-use cyber-physical technologies like the drone become adopted across contexts. In exploring these emerging complexities and developing conceptual and analytical tools to better understand it, this work makes significant contributions to the understanding of both ambiguity and drones within international relations, security studies, and related disciplines, offering an important benchmark for re-conceptualising the influence of complex remote-physical technologies within the international arena and paving the way for future studies pertaining to the effects of such technologies beyond those for which they were initially designed or intended.

2. Literature Review

The rapid proliferation of drones in the post-9/11 era has seen a large body of scholarly work emerge in relation to drone use in the context of security and conflict. Spanning multiple disciplines, including Politics, International Relations, Human Geography, Science and Technology Studies, and Sociology, the study of drone use and its implications for society is far reaching. Much of this work emerged against the backdrop of targeted killing practices using lethal drones in the War on Terror (WoT). This first wave of contemporary scholarship on drones subsequently emerged within this context, with a recurring focus across disciplines on the legality, morality, and ethics of targeted killing practices. This review does not attempt to rehash these important debates; they are not the focus of this research and have been widely and comprehensively covered by others in impressive depth (Boyle 2015; Warrior 2015; M. Orr 2011; Ian, G. R. Shaw and Akhter 2012; B. Williams 2013; Chamayou 2015; Benjamin 2013; Grayson 2016a; Woods 2015; Weber 2017; Calhoun 2015). Following this first wave of literature, a second major focus dominating the discourse on drones has been critical inquiry into the continued use of drone technology beyond the context of conflict. For example, scholars have focused on the problematic implications arising from the drone's integration with everyday security practices (Ian, G. R. Shaw 2016; Ian G R Shaw 2017; Koslowski and Schulzke 2018). This critical discourse, while diverging from the first wave of drone warfare literature, remains tightly bound to the legacy of the WoT, drawing our attention to the normalisation of drone-related security practices that it has given rise to. While these discussions continue to hold value, the geopolitical landscape is shifting away from the unipolar, U.S dominated system within which much of this work emerged. The rise of a multipolar international system – against this backdrop of waning U.S dominance – is ushering in new dynamics and actors that must be taken into account when considering contemporary drone use and practices. At the same time, the adoption, development, and use of drones has also seen significant shifts over the last decade. The proliferation of lethal drones, coupled with the rise of commercially available drone technology has added new layers of complexity to the implications of drones.

These changes paved the way for a shift in the drone discourse, with work emerging over the past ten years in relation to the implications of commercially available consumer drones for conflict and security. A focus on the risks and threats of consumer drones utilised by terrorists and other non-state actors has been at the forefront of these conversations (Dunn 2013; Sims 2018; Bunker, Sullivan, and Kuhn 2021; Rossiter 2018; Ball 2017; Rassler 2016; Rogers 2021a; Jackman 2019; Cronin 2019). The ease with which consumer drones can be acquired by violent non-state actors and the blurring of lines between military and commercial drone contexts, has further led to works focusing on the implications of the proliferation and dual-use nature of drone technology (Schulzke 2019; M. Hughes

and Hess 2016; Chávez and Swed 2021; Ball 2017). However, there is much more to learn about drone technology within the complex and emergent geopolitical landscape within which they are being adopted and used. The fast-paced and evolving nature of drone technology itself, the multiplicity of their adoption across both military and civilian contexts, and the new practices we are seeing emerge around their production, modification, and use, are yet to be fully elucidated. The drone is undergoing continual change in terms of its capabilities, form, and functions. These evolutions, coupled with changes to how we are seeing drones utilised in novel ways provoke important questions around what these changes mean for security and international relations more broadly. Importantly, these are questions not yet fully attended to in the literature. As outlined in the introduction, a growing number of observable instances of deniability surrounding drone use have come to pass in recent years. These incidents often give rise to confusion and dispute around culpability and attribution relating to drone incidents and usage. Such incidents beckon us to question the role disruptive technologies —such as the drone— might play in intensifying conditions of ambiguity often already pervading contemporary conflict. Drones are often utilised precisely with the aim to *diminish* ambiguity and uncertainty in conflict by providing enhanced situational awareness; allowing more information to be gathered and distributed to make operations on the ground less opaque. Yet, as we are beginning to see, drones and their use may be adding to the opacities of conflict by generating ambiguity both inadvertently and intentionally. The drone is fast emerging as a tool capable of sowing confusion and deniability around its use. Moreover, we can observe this phenomenon occurring within the context of conflict and beyond it in domestic security settings, and within the context of both weaponised and non-weaponised drones. This opens important avenues of inquiry around agency and the drone's capacity to *create*, *enable*, or *produce* certain effects or conditions. As the use of consumer drone technology increases in our societies, a deeper understanding of drone technology and its potential capacities to wield *novel forms of influence and effect* both in and beyond situations of conflict is of critical importance. We already do not fully understand the implications of drone use; this is compounded by its continuing evolution in form, capability, and practices of use. Indeed, if the drones of today can facilitate deniable, destructive, and disruptive events, what does this mean for contemporary conflict and security going forward as science and technology drive the drone as we currently know it to new forms, functions, and contexts? These questions are yet to be explored in both International Relations scholarship, Security Studies, and the wider drone discourse.

Accordingly, this review takes a thematic approach to explore literature across three areas relevant to this inquiry: the advent of consumer drone technology; critical perspectives on drones and non-human agency; and the concept of ambiguity in relation to drone use. First, it looks at work on the concept of ambiguity in direct relation to the study of drone technology to assess the extent to which this has been considered. Second, it turns to work within Critical Security Studies to understand the ways in

which scholars have sought to look beyond the drone to its wider implications, associations, and effects. Lastly, it looks at consumer drones and their implications for contemporary security and conflict. In doing so, this review highlights key gaps in our understanding of the increasingly complex device that is the drone and illuminates the value that can be added to the discourse on drones by bringing these three areas into dialogue with each other.

2.1 Drones and Ambiguity

Ambiguity – the capacity for something to be "interpreted in more than one way" (Oxford English Dictionary 2023b) – is an intrinsic element of contemporary conflict. While the concept of uncertainty has a long tradition in war and conflict discussions (Clausewitz 1993, 117; Waldman 2010b; Kolenda 2002b), ambiguity has drawn less scholarly attention (Mumford 2020, 3). Furthermore, in comparison to concepts such as uncertainty and risk, ambiguity has received little focus in International Relations scholarship (Best 2008, 355; Ramsay 2017b; Debs and Monteiro 2014). The presence of ambiguity has been acknowledged within various conceptions of conflict, with many terms developed to encapsulate modes of unconventional conflict typically involving ambiguity in the tactics utilised (Hoffman 2016b; Votel et al. 2016b). As discussed in Chapter 1, the concept of ambiguity has an important place in the study of conflict. It is emerging as a topic warranting more significant attention in the contemporary security and conflict landscape, as some research groups aptly noted in previous years (Changing Character of War Centre 2017). However, ambiguity as both a phenomenon and concept has not been adequately or meaningfully explored beyond the context of nuclear deterrence as discussed in detail in Chapter 1 (Baylis 1995, 5–6).

Mumford, in his report *Ambiguity in Hybrid Warfare*, begins to remedy this gap by providing an exploration of ambiguity in the context of hybrid warfare (Mumford 2020). For Mumford, the primary aim of ambiguity in hybrid warfare is "not necessarily to hide the true actor behind the activity, but ultimately to stymie a legitimate response" (Mumford 2020, 3). Building on this, Mumford and Carlucci make further useful strides to develop our understanding of ambiguity through an elucidation of its nature, characteristics, and value in the specific context of hybrid warfare (Carlucci and Mumford 2023, 192). They importantly highlight that ambiguity gives rise to "cognitive impasse" for the individual or situation subject to it, directly impacting how war is conducted (Carlucci and Mumford 2023, 198). Furthermore, they list drones among a suite of other means used to *generate* ambiguity in hybrid warfare, alongside things like separatist forces, artillery, propaganda, and legal claims (Carlucci and Mumford 2023, 199). What Mumford and Carlucci's assessment of ambiguity lacks, is a meaningful exposition of *how* certain tactics or tools incite the very ambiguity they seek to explore. While evidently beyond the scope of their research – the authors indeed assert they will look

only at ‘why’ hybrid warfare exists rather than ‘how’ (Carlucci and Mumford 2023, 197) – closer attention to *how* certain conditions are created through the tools and tactics is integral to being able to fully comprehend them. This is no less true of ambiguity. As Cronin notes in her work, certain tools are emerging as more fitting for certain strategies in conflict than others, and understanding *why* this is the case, and what attributes make some tools and techniques more attractive options than others is crucial (Cronin 2019). While bringing an important and much needed focus to the study of ambiguity in warfare, Mumford and Carlucci’s work on ambiguity is ultimately limited in its exposition of how ambiguity arises. With little inquiry into where, or more importantly *how*, the condition of ambiguity arises through the use of certain means, the work takes the existence of the phenomenon as a given, instead of seeking to understand its origins, roots, or dynamics. Moreover, while their work does reinforce the importance of ambiguity as a central consideration within the study of conflict, it falls short of developing an understanding of how ambiguity might apply to contexts other than hybrid warfare. What are the implications of ambiguity (and the *things* that generate it) more broadly for international relations, security, and conflict? This work does, however, affirm the relevance of bringing the technology of the drone into conversation with the concept of ambiguity. Although the authors only fleetingly mention drone technology, they highlight it as a tool that can be used to purposefully drive an adversary into a “cognitive impasse” (Carlucci and Mumford 2023, 199). Though, they make no attempt to unpack the mechanisms or components that come together to allow, enable, or afford this. There is thus a deeper and more nuanced conversation to be had here to understand these dynamics, and it is here that bringing the drone into dialogue with ambiguity using a material-oriented perspective can offer insights previously unexplored. Furthermore, this conversation is valuable beyond the context of hybrid warfare; the widespread adoption and use of drone technology presents a complex contemporary landscape of drones use beyond the realms of war. A deeper understanding of the interplay and interaction between drone technology and the phenomenon of ambiguity thus holds value for broader international relations, security and conflict.

We can understand drone technology in the contemporary age as a device harnessed, in many ways, to combat forms of ambiguity and uncertainty – for instance, through their capacity to enhance situational awareness. Yet, we are beginning to observe ways in which this device might contribute to or heighten ambiguity in various ways, as outlined in Chapter 1. This beckons a crucial question: how do we begin to conceptualise an emerging environment increasingly saturated with systems with the potential to give rise to the very condition they aimed to diminish?

Aspects of ambiguity related to the use of drones have been explored in the context of legal and moral ambiguities surrounding remote warfare and targeted killing. For example, several scholars highlight the insufficient mechanisms of accountability and transparency that drone technology facilitates (Boyle 2015; Warrior 2015). Indeed, the remote nature of this technology, facilitating its use across

jurisdictions and international borders, has sparked much significant debate regarding the drone's impact on – and blurring of – traditional notions of sovereignty and the legal and moral ambiguities this gives rise to (D. R. Brunstetter and Férey 2021; Adam Smith 2022; Munro 2015; Rodríguez Mojica 2022). Beyond the ethical and legal contexts, however, consideration of ambiguity in the context of drone technology is scarce. One recent exception can be found in Kaplan's work which presents a fascinating account of how the use of small drones by multiple parties in the same airspace contributes to what she terms an "ambiguity of the airspace" (Kaplan 2020, 51). Certainly, this work provides important insight into some of the complexities arising around consumer drone use; where accessibility to this technology provides access to the air to a multiplicity of actors with differing agendas. Crucially, Kaplan's material analysis provokes us to reconceptualise the airspace in the age of drones, as one "…produced by assemblages of human and machine…" (Kaplan 2020, 52). In so doing, she highlights that we can understand the airspace through a plethora of material things, practices, and activities.

More recently, Hwang has explored the utility of the drone in gray zone strategies, which are widely acknowledged for their ambiguous qualities (Hoffman 2016c; Freier et al. 2016, 4; Brands 2016, 1; Wirtz 2017, 107; Kapusta 2015, 20). Hwang draws parallels between the gray zone and drones, highlighting the common quality of ambiguity between them. He asserts drone use can be "ambiguous in many ways" due to it enabling actors to "feign innocence" and "dodge accusations" over their use (Hwang 2021, 336–39). This is an important point, underscoring the importance of bringing drone technology more closely into dialogue with the concept of ambiguity. Indeed, the emerging deniability surrounding drone use, as explained in Chapter 1, is of key interest to this work. Hwang's paper argues the drone is apt for gray zone use and goes on to describe three ways in which drones are being used in this context. First, he discusses the use of drones for typical gray zone salami slicing tactics; an approach to territorial provocation that is both gradual and ambiguous (Hwang 2021, 337). Second, he discusses the way in which drones, and particularly the lack of a pilot, facilitates denial of involvement and the feigning of innocence when it comes to drone incursions and shoot downs. In addition, he talks about drones being used by proxy forces to avoid direct confrontations in a way that can maintain ambiguity (Hwang 2021, 338–39). While Hwang's work takes some useful steps towards positioning the drone as a technology useful in ambiguous strategies, the paper misses a vital opportunity to expose and elaborate on the properties of drone technology that facilitate some of these usages. Indeed, the paper ultimately fails to go beyond a rudimentary and descriptive assessment of the drone and its relationship with ambiguity. Although it provides a useful account of how the drone might be used by revisionists employing a gray zone approach, the work makes little attempt to elucidate the deeper dynamics at play with this complex socio-technical device that make those uses a possibility or make them effective. It seems there is more at play here than simply the drone's low cost and lack of a pilot; the two main features described in Hwang's account that make the drone apt

for ambiguous strategies. It is within this context that there exists a significant gap in our understanding of the contemporary drone and its use. This is a vast socio-technical system whose properties are constantly changing and expanding due to shifts in technology and usage. Some scholars have clearly recognised the deniability of drone use in some contexts, however, the absence of a comprehensive account investigating the origins and properties of ambiguity surrounding drone use is notable. What makes denials around drone use legitimate or plausible? What underlying properties drive the plausibility, or allow for ambiguity to be generated and maintained? A deeper analysis of ambiguity relating to the drone – specifically consideration of the drone's extrinsic and intrinsic properties lending to multiple forms of ambiguity is sufficiently lacking. These inquiries are essential for our understanding of the drone going forward and to assist in disambiguating the drone. This thesis strives to bridge this lapse to elucidate the diversity of factors contributing to the drone's deniability and its emerging enigmatic role in contemporary conflict. Drones – and ambiguity pertaining to their use - present a fascinating case for critical scrutiny, to investigate how they relate to and intersect with broader material factors and forces underpinning modern conflict. Approaches in Critical Security Studies can assist in unpacking the socio-technical complexities of the use of such devices as drones and can help elucidate unintended consequences arising from their use. It is to this area that we turn next.

2.2 Drones in Critical Security Studies

Emerging and disruptive technologies, including drones, are reshaping the landscape of security by redefining the relationship between technological innovation, state power, and the evolving character of conflict (Steff, Burton, and Soare 2020). Drone technology has gained much attention in this regard due to its arguably transformative potential in contemporary conflict and security practices (Boyle 2022). From the capacity to facilitate lethal 'precision' strikes in the military context, to offering the ability to conduct persistent and pervasive surveillance in both military and civilian capacities, drone technology has played a crucial role in reshaping aspects of military capability, intelligence, and state security practices. The proliferation of drone technology has also beckoned important questions about the impact of such disruptive technologies on international stability and arms control (Morley 2014; Zenko and Kreps 2014; Boussios 2014). At the same time, this technology prompts us to question the role of disruptive technologies like drones in the increasingly blurry line between military and security practices. Drone technology provides a rich site for many avenues of critical scholarly investigation, and this continues to grow as drone technology —and the ways it is used— continues to evolve.

As a multidisciplinary field, Critical Security Studies (CSS) has a breadth of contributions related to the implications of drone technology in the context of conflict and security from scholars spanning a diverse range of disciplines. This work provides unique perspectives that prompt us to think differently about security and, indeed, the drone itself. Voices contributing to this area strive to raise the little-considered aspects underlying the socio-technical phenomena that is drone technology, its adoption, and application. Understanding the materiality of weapons, how they come to be, how they work, how they are used, and their evolution, is important for critical scholars within IR (Bousquet, Grove, and Shah 2017; Edney-Browne 2019). Understanding the components, associations, effects, and trajectories that make up a weapon and its use provide insights that conventional security perspectives tend to overlook – and the drone is no exception. The drone is a complex socio-technical system. To effectively think critically about this technology and its use, we should strive for a deeper understanding of the components, practices, and processes that make up and sit around its existence and use. The 'material turn' in international relations scholarship strives to do just that. It refers to an increased focus on the material *things* and objects that make up our world, and their intricate – although not always self-evident – connections to political practices and international relations. A broader body of work has thus emerged within CSS seeking to expose the deeper workings and implications of drone technology in security and conflict from material-oriented perspectives. These approaches often focus on aspects of non-human agency in the context of the drone. It is in this context that they lean away from the state-centric focus that has pervaded much of the conventional drone discourse within IR over the last two decades. By focusing on 'matter' of various sorts and combination, material-oriented perspectives offer us a unique window into the underlying facets that combine to 'produce' the drone, its uses, practices, and effects.[1] Indeed, this body of work aligns with an understanding of security as something that is "socially constructed and politically powerful" (Browning and McDonald 2011). These perspectives have importantly demonstrated some of the external factors, trajectories and internal dynamics at play in relation to drone technology and practices of use that other approaches miss or overlook. It is here that material analyses of drones in CSS make significant contributions to our understanding of this disruptive technology and its implications for security and society more broadly.

Scholars have investigated the various external influences underpinning contemporary drones and their use through particular focus on their broader geopolitical, historical, and socio-technical contexts and trajectories. Bousquet (2008) for example shows us how modern military strategies – including the use of technologies like drones – are embedded within wider ideological and political structures. In his analysis of "chaoplexic warfare", Bousquet exposes these strategies as situated within

[1] New Materialism as a framework is detailed at length in Chapter 3, Methodology. The focus here is not on materialist methods themselves, rather, on what they expose about drone technology and its use.

epistemological frameworks that attempt to assert control, order, and predictability on the conduct of security and war. In doing so, his work explores how self-organising and adaptive systems are prone to failures and problems, revealing how such attempts often lead to unintended outcomes, exacerbate unpredictability, and introduce more uncertainty rather than achieving control over it (Bousquet 2008). This line of thinking challenges the underlying techno-deterministic logic that seems to underpin much of the military's over-reliance on technology for accuracy, speed, certainty, and control to achieve security. This ultimately poses new questions in the face of technologies like drones which are emerging as new vectors of confusion and disruption in the 21st Century, rather than tools ensuring control and security. Such techno-deterministic critiques resonate with a broader body of scholarship examining the complex extension of agency that robotic warfare represents in the post-9-11 era which show how the use of technologies like drones are entangled deeply in various ethical, political, social, and spatial dynamics. This body of work is far reaching, spanning beyond security studies and international relations, to many other disciplines including human geography, media studies, and law (D. Gregory 2011a; Ian, G. R. Shaw 2016; Ian G R Shaw 2017; A. J. Williams 2011; Leander 2013; Wilcox 2015a; Chamayou 2015; Parks 2016; Shapiro 2007).

Scholars have sought to elucidate the drone's facilitatory role in extending forms of power and control over populations, serving as tools that can facilitate governance and surveillance from afar (Barrinha and da Mota 2017; Agius 2017). Other scholars have examined how drones usher in new modes of subjectivity and political violence through making some groups hyper-visible while discounting or obscuring others, showing how drones produce asymmetrical visibility and particular ways of seeing that shape and reshape violence, power, and agency (Allinson 2015; D. Gregory 2011a; Edney-Browne 2019; Graae and Maurer 2021). Connecting to these analyses of power and visibility is the broader concept of 'visual and scopic regimes' which situates the drone's optical reframing of violence against a longer history and lineage of technological and scientific developments, practices, and broader systems of visual control and surveillance (Kindervater 2017; Bousquet 2017; 2018; K. Maurer 2016; Grayson and Mawdsley 2018; Edney-Browne 2019).

Assemblage thinking, a key facet of materialist thinking, has proved useful for examining complex socio-technical systems such as the drone and the array of external factors playing into practices surrounding its adoption and use. Grayson (2016a) puts forward a compelling investigation of targeted killing practices, drawing our attention to the assemblage of factors that sits around this now-established practice to demonstrate how drone warfare has been politically and culturally constructed as a necessity. In assessing the problem by looking beyond the drone itself, Grayson illustrates how a variety of external factors, from cognitive frameworks influenced by science, economics, and military doctrine, to cultural norms, prominently contribute to the drone's adoption into present-day security practices. A further example can be found in the work of Pugliese, who embarks on a critique of

drone warfare using the lens of the "disposition matrix" to expose the ways in which drones rearrange the global landscape based on power dynamics that are unequal (Pugliese 2015, 225). He draws on both a Latourian understanding of actors, things having the capacity to afford, permit, influence, and assemblage thinking, to map out the "material resonances" such as institutions, sites, and technologies that make up and enable a certain set of practices around drone use (Pugliese 2015, 231). Cumulatively, these critical approaches expose how the drone's existence is entangled with an array of factors, including historical trajectories in modern science and technology, and ideological and political factors that have paved the way for the contemporary drone's capacities and its associated practices of lethal surveillance.

This surge in critical scholarship has occurred against the backdrop of ethical and political concerns around practices of security becoming increasingly imbued with algorithmic procedures. Indeed, these concerns have led other scholars to focus their attention on the internal aspects of the drone, specifically on the algorithmic and computational dimension of drone technology and its implications for security (Emery 2022; Wilcox 2016; 2015b; Gibson 2021; Rauer 2016; Suchman 2020). The material turn in IR and CSS has given rise to more granular critical engagement with the notion of agency in the context of the drone. With a view to illuminating the complicated entanglement of the human and machine in contemporary security and war, this body of work compels us to consider the intersection of military technologies with human and non-human agency. In focusing on different facets of algorithmic security, some scholars engaging with the critical materialist perspective call our attention to an understanding of algorithms as embodied 'actors' with the capacity to transform and shape decision-making and security practices (Wilcox 2016; Amoore and Raley 2016). In this context, Wilcox argues against conventional notions of drone warfare as being detached and removed from the human, instead highlighting the "embodied and embodying" nature of the human-algorithm interface (Wilcox 2016). Resonating with this discussion of embodiment, others have sought to highlight the intersection of information and corporeality (using drones as one example) and its importance for understanding how power functions (Marlin-Bennett 2013, 620). Moreover, Suchman's (2020) feminist socio-technical critique of automated warfare presents a central challenge to the idea of technological neutrality, interrogating how algorithms obscure human agency arguing that in the process, it abstracts ethical and political responsibility from practices of drone use. These scholars, while taking different points of focus, coalesce in their use of drones to challenge conventional understandings and assumptions around human control, distinctions between the material and immaterial, the human and non-human, and the physical and the virtual. This focus is integral to furthering understandings of drones in contemporary security and conflict, allowing us to critically assess the tangible and intangible materiality of the human-technology assemblage at the heart of drone usage, and the new forms of agency it may give rise to.

Caroline Holmqvist's critical materialist analysis of drone warfare in 'Undoing War' puts forward a compelling case that does just this, taking into consideration the tangle of "fleshy and steely bodies" enmeshed and blurred in the phenomenon of drone warfare (Holmqvist 2013). She refers to a "complex assemblage of virtual and material experiences" produced by drone warfare, channelling the philosophies of Butler and Merleau-Ponty in her re-evaluation of the human experience in the contemporary era of robotic warfare. In doing this, Holmqvist challenges long-standing conceptions surrounding drone warfare related to the detachment of the human, calling instead for a transformation in thinking about the role of the human in war. Importantly, one of her central claims is that "the corporeal and the incorporeal are blurred in contemporary conflict". This bleeding together of the physical (material), and the non-physical (immaterial) is a crucial conceptualisation for evolving our understandings of contemporary war. Holmqvist makes a point of highlighting that the drone's capacity to 'act' does not rest in its increasing autonomy: "developments towards decision making capabilities on the part of drones, and, crucially, their capacity to decide to attack, are no doubt alarming…yet the question of whether the drone ought to be seen as 'acting' does not reside here" (Holmqvist 2013). While she makes a valid point in her argument here that we can *already* consider the drone a political agent, this analysis adopts a constrained view as to what increasing autonomy in the drone might – to follow Latour – "allow, afford, or enable" (Latour 1992). Indeed, much of the discussion around drone autonomy from materialist perspectives is highly preoccupied with questions of lethal morality and the ethics of allowing a machine to make lethal decisions. This is a warranted concern, however, the challenges of autonomy extend to other facets of the drone beyond lethal decision making. A drone's autonomy can play a part in its intrinsic functioning, behaviour, and in some cases, physical configuration, all of which can directly and indirectly hold implications for how they are used, and the effects of that usage. When we begin to consider the plethora of other *things* that increasing autonomy *affords, allows, or permits*, new questions are raised regarding whether we should consider autonomy when thinking about the drone's capacity to 'act'. This is something yet to be meaningfully explored. A material analysis of the drone that considers its continually transforming cyber-physicality – including the multiplicity of ways autonomy interacts and interplays with its use and functioning – holds promise to deepen our understanding of the drone and its use further.

These approaches – whether the focus of analysis is on the external historical, political, ethical, social trajectories that have made the drone and its use what it is today, or on the internal algorithmic processes at play and the challenges this presents – show us that the contemporary drone is a collection of 'things' interacting within broader systems of knowledge, power, and socio-technical relations. Importantly, none of these external or internal aspects are isolated – there is a rich interplay underpinning them which materialist approaches allow for the exploration of. Indeed, as Grayson highlights (2016b, 326), the drone's internal aspects can interact with external forces to generate

unintended effects or "excesses". Through an exploration of the political economy surrounding the drone's adoption, its entanglement with network-centric warfare, its capacity to produce modes of affect and embodiment, and the drone's emerging role as an actant in and of itself, Grayson sets forth a wide-reaching account of the many ways in which we can observe the drone "shaping the international". It is this latter focus in Grayson's analysis that resonates most with this thesis. The capacity for the drone itself to 'act', and the ways in which this might manifest are central. It is within this context that Grayson poignantly states: "…it would be nearsighted to overlook the ways in which drones through their complexity might actively shape the international in ways that go beyond human control and/or intention." (Grayson 2016b, 333). He goes on to talk about two specific forms of 'excess' where we can observe the drone "going beyond human intention" and which can be understood in the context of agency: its capacity to "go rogue" in situations where control is lost, for example; and in the drone's capacity to be "harnessed and/or reconfigured for purposes not intended by their operators" – such as hacking by external parties (Grayson 2016b, 333–34). This line of thinking is important, as it begins to push our thinking about what the drone is capable of, and what it may facilitate, enable, or initiate, into new realms. Given the ever-changing nature of drone technology – which continues to undergo rapid innovation in both the military and civilian sectors – broadening our thinking about the notion of agentic capacity and the drone is necessary.

Meiches adds to the discussion of ways in which we can observe the drone going beyond human intention. He argues that weapons, including drones, can be understood as "agentic entities" which have influence over the desires of humans, producing a desire for particular forms of war (Meiches 2017a, 22). Similar to the approaches of Kindervater and Bousquet, Meiches situates this within a longer lineage of weaponry, situating the drone's 'production' of desire against a broader trend within weaponry and technologies and war, rather than the production of desire in and of itself being unique only to the drone. These approaches, however, while offering an important insight and reminder of the wider historical contexts within which the drone and aspects of its use have emerged, miss the evolving aspect of the drone's materiality that may give rise to – or produce – novel capacities or effects. Certainly, it is the capacity for technology, whether drone related or not, to 'produce' and 'shape' behaviours or other conditions that is of key interest here. Grayson's attention to the emerging excesses around drones and their use with respect to reconfigurations, going rogue, and unintentional uses, begins a crucial conversation that has not been subsequently attended to in more detail within material-oriented (or other) analyses of the drone. This thesis is interested not only in such 'excesses' as outlined by Grayson, but in the effects, practices, and implications such excesses might have on drone practices and the international. Indeed, in Grayson's (2016b, 335) proposition of drones as "engaged forces that actively shape the future of the international," there is still much to be explored.

These critical approaches highlight the necessity of interrogating technologies like drones not only as tools of lethal surveillance and strike, but as entities that are shaped by an array of material components spanning technical aspects, scientific knowledge, operational logics, and broader political contexts. These intersections compel us to reconsider our thinking on control, agency, and the production of unintended effects in relation to drone technology as these many and various entanglements make more complex the drone and practices of use surrounding it. Material perspectives on security have brought to light some of the 'things' that drones can 'produce'. From generating unique forms of remote-distance or intimacy (Gusterson 2016, 59–81), triggering political disputes or controversies (Walters 2014, 104), to shaping security practices (Holmqvist 2013; Grayson 2016a) and driving human desire for certain kinds of war (Meiches 2017b, 22). The potential for material approaches to critically engage with security matters in a way that brings to light ways in which the drone has the capacity to generate 'things', effects, and in turn shape the international is evident. However, much of the material-oriented critical scholarship on drones has, until recently, been heavily focused on the use of military lethal drones for targeted killing in the post-9/11 era. There has been less focus regarding the emergence and widespread adoption of consumer drones, although there are some notable exceptions. As the use of consumer drone technology becomes increasingly ubiquitous, attention is slowly turning toward unpacking the complexities of the consumer drone and its use. It is within this context that Kaplan draws our attention to an interesting socio-technical assemblage emerging as multiple actors utilise drones for various purposes (Kaplan 2020). Her analysis emphasises the multiplicity of competing operators and narratives in situations where drones are being flown by protestors, police, and journalists in the same airspace. She highlights how airspace restrictions placed on those using drone technology to 'witness' or document state violence can lead to the airspace *itself* becoming a medium of state violence (Kaplan 2020). By shifting the focus to the actors involved in the utilisation of drones in this case, a new set of questions are raised and critically addressed. A further example can be found in Crampton's understanding of the drone as a "socio-technical assemblage of the sky and vertical space" (Crampton 2016, 137). He highlights the potential for new forms of subjectivity to be created by the drone, specifically against the backdrop of a wider series of trends pertaining to 'algorithmic governance' through the collection of biometric data and surveillance (Crampton 2016, 141). Specifically, he emphasises the expanding nature of the consumer drone market and critically calls our attention to the spectrum of actors with a vested interested in such expansion and the implications therein. As Crampton notes, '[t]he components of an assemblage such as that of the commercial drone have been brought together deliberately and always benefit someone or something outside the assemblage' (Crampton 2016, 138).

These approaches demonstrate the complexities emerging from the evolving object of the drone and its use. There exist multiple constellations of factors around it that contribute to any one aspect of its use. Material-oriented perspectives demonstrate utility in studies attempting to make sense of, or map

out, various aspects that contribute to a certain phenomenon, situation, or 'thing' consequent the drone and its use. While work exists in this area pertaining to drone strikes, targeted killing and the use of drones in certain security roles, there is a lapse in the discussion pertaining to strategic or other non-lethal 'effects' consequent of drone technology and its use both within and outside of conflict. As mentioned previously, the circumstances of drone adoption and utilisation across the globe have vastly altered since much of this prior work on drones came about. The adoption and use of drones, both military and civilian, has become more complex, widespread, and fragmented. Not only do more states have access to military drones than ever before, but the increasing development and adoption of consumer drones in the context of both military arsenals, non-state actors, and civilian contexts, has added a deeper level of complexity to the global drone landscape that much prior work does not capture, unpack, or explore (Gettinger 2019). Indeed, this growing plurality of drones, used across different contexts and for different purposes beyond targeted killing and lethality, adds new dimensions to the use of drones that invite important new questions about what the fragmentation of drone use and their plurality in the international system mean for the international. While there has been a conscious focus from critical scholars on looking beyond the drone to uncover its wider associations and implications, this research is interested in what we might also learn when we look directly at the technology and the material components that make up its existence and enable its use. What constellation – or assemblage – of other things or factors will emerge as important to the ongoing drone conversation from looking to the technology itself and the components that 'make' it? How do material aspects of the drone's configuration and construction play a role in the effects it can produce? Moreover, how are practices of drone use being shaped by material forces, and what are the implications for security, conflict, and the international?

This section has considered the growing body of work within Critical Security Studies that attends to the drone through material-oriented approaches and perspectives. CSS has produced a useful body of work that unpacks the drone and implications of its use from unique perspectives. These perspectives invite us to critically interrogate different dimensions of the phenomenon of the drone. Importantly, they allow us to question and piece together how the drone both comes to be and how it is used. Moreover, they prompt us to engage with difficult questions around what the drone, its capabilities, and uses, might allow or permit. At the forefront of these discussions have been the use of military drones for targeted killing and their transformative impacts on practices of security and political violence. A significant gap in this body of work exists in that most work does not place emphasis on a material understanding of 'effects' beyond lethality, targeted killing practices, and the associated practices of surveillance and control they facilitate. While this preoccupation is understandable, as previously mentioned, the landscape of drone use has become more complex as a consequence of the growing accessibility and ubiquity of drones, in addition to the advent of consumer drone technology and its widespread adoption. Moreover, the rapid and continuous evolution of drone technology

renders it an object whose utility and functionality is not static. With vast capacity for modification and novel usage, a detailed exposition of these material evolutions would benefit our understanding of the drone and its evolving role in shaping the international. Furthermore, there are other dimensions to the materiality of the drone that are yet to be meaningfully explored and exposed. The drone's role in shaping certain strategic, and other, non-lethal effects is one example. As outlined in Chapter 1, the drone has emerged as a tool capable of causing vast disruption in both domestic and international contexts. Moreover, we can frequently observe the use of drones in deniable contexts, with those responsible denying or successfully evading culpability. The drone has thus emerged as a tool that can be leveraged to achieve certain effects that impact one's capacity to respond or fully understand a situation. These capacities of the drone to give rise to certain conditions like confusion or ambiguity align with the kind of excesses Grayson has previously discussed in the context of the drone producing things beyond their initial intention (Grayson 2016b, 333). This would benefit from being brought into conversation with existing understandings of agentic capacity in relation to the drone and the wider discourse on drones and international security. When looking to understand such excesses, the drone's materiality – what enables that device to exist both physically and digitally – as well as its ongoing evolution, requires more scrutiny.

2.3 The Advent of Consumer Drone Technology

The drone has evolved beyond its use in lethal surveillance and targeted killing. The 21st Century has seen the creation and expansion of a vast and easily accessible consumer drone market that is changing the narrative of drone use. Today, consumer drones can be purchased easily by anyone with access to the internet. Access to the air has become affordable and highly accessible. With this change has come an important shift in the discussion and debate surrounding drone technology related to how this accessibility offers both benefits and threats to society. The various opportunities and benefits consumer drones offer are wide ranging. The capacity for drones to reach areas inaccessible to humans to aid in humanitarian and emergency rescue efforts is one key example (Martini et al. 2016). However, reach is not the only benefit such system have to offer. Contemporary consumer drones can carry various sensor payloads, allowing them to do a range of tasks previously unattainable (Z. Zhang and Zhu 2023). The adoption of consumer drones has thus been vast; their use can be observed across a multitude of sectors and applications, from agriculture, logistics, and telecommunications, to photography, film, and security (PricewaterhouseCoopers 2016). There is much work showcasing the advantages and good that the advent of consumer drones can offer society (Choi-Fitzpatrick 2014; Sandvik and Jumbert 2016). However, as with most technological innovations, there are also ways they can be misused. Following the emergence of terrorist groups actively using modified and weaponised consumer drones in Iraq and Syria during late 2016, the scale of ways in which consumer

drones might be misused came into focus (B. Watson 2017). The threats posed by the adoption of such drones by violent non-state actors began to take centre stage in discussions surrounding their use (Rassler 2016; Ball 2017). A broader body of work has since emerged attuned to assessing and understanding the implications, risks, and threats stemming from the accessibility of consumer drones when in the hands of a plethora of different actors (Abbott, Clarke, and Hickie 2016; Hastings-Dunn and Wyatt 2018; Rogers 2019a; Rossiter 2018; M. Hughes and Hess 2016; Krame, Vivoda, and Davies 2023; Bressler and Bressler 2016; Jackman 2019). Two central components of the consumer drone's utility in this regard are its accessibility and its capacity to be adapted to various applications. The accessibility of such drones has garnered significant attention, particularly related to work on the proliferation of small drones (Chávez and Swed 2021), the supply chains and networks facilitating their attainability, and the dual-use dilemma at the heart of the technology itself (Novitzky, Kokkeler, and Verbeek 2018; Schulzke 2019). The adaptability surrounding their use has received less scholarly attention. While the adaptability of consumer drones to a multitude of applications is often widely acknowledged, meaningful exploration and unpacking of this quality is lacking. However, this has begun to change as the transformative and seemingly ever-changing nature of consumer drone technology becomes increasingly evident. Interestingly, these explorations have predominantly occurred in other disciplines, human geography (Jackman 2019) and media studies (Bender and Burkhardt 2023) being two key examples.

Jackman's work on consumer drone risk and threat makes crucial headway towards a better understanding of drone adaptability (Jackman 2019). She draws our attention away from the military narratives that have pervaded drone scholarship over the last two decades to focus on the domestic deployment of accessible and adaptable consumer drones and their associated risks. This work marks an important shift and advancement of discussions around consumer drones; acknowledging the transformative change in the drone landscape that consumer drones represent. Importantly, Jackman highlights the necessity for our thinking about drones to change along with this transformation of the drone landscape. Specifically, she calls for wider consideration of the dual aspect of both potential and threat domestically deployed consumer drones hold. Through an analysis of consumer drone innovation, technical advancements, and exploration of the DIY drone community, Jackman unpacks crucial aspects of the consumer drone's accessibility and adaptability. She draws our attention to the "inherently malleable" nature of the consumer drone, considering it a central factor to our understanding of the consumer drone's capacity to be repurposed and modified for nefarious applications (Jackman 2019, 367). By paying specific attention to the array of 'sites' giving rise to creative drone modification and innovation – from online drone communities to industry innovation – she maps an underlying ecosystem of networks and associations to broaden our understanding of drone risk and where it can materialise. Jackman's work makes an important contribution to assist in developing a more nuanced understanding of the contemporary drone and the implications of its

capacity to be modified. While Jackman's concept of drone malleability is useful in capturing the drone's capacity to be put to a multiplicity of uses, it stops short of capturing the drone's *internal capacity* to change. While Jackman does indeed recognise some non-physical modifications that can occur with drones, such as the capacity for hacking height restricting software (Jackman 2019, 372), the *digital modification potential* of the drone goes beyond this and is not attended to by Jackman's reading of drone modification. With increasing levels of autonomy comes increasing self-determinism in the drone, allowing the drone itself to alter various aspects of its functionality and even form in response to its surroundings. Investigation of these internal alterations and their implications for the broader application and understanding of consumer drone modification is required.

Consumer drones, while offering certain novel capabilities, are not the first or only technological innovation to become widely accessible, thus introducing new risks in the hands of individuals. The growing ubiquity of cheap, accessible drones sits amid a plethora of previous innovations which, as Cronin highlights in her work, show a similar pattern of diffusion (Cronin 2019, 13). Cronin's work in *Power to the People* draws on historical examples to demonstrate that terrorists and other violent actors have a long history of taking advantage of emerging innovations for violence. The difference today, she argues, is the range of actors now involved in "open innovation" (from professionals to hobbyists) and the facilitatory effect this has on the diffusion of lethal technologies – including consumer drones (Cronin 2019, 13). Cronin posits a *theory of lethal empowerment* which seeks to guide our understanding of why some disruptive, lethal technologies are more likely to become popular tools wielded by violent non-state actors than others. At the heart of her theory are a series of characteristics outlined as key to such technologies being adopted in this way. For Cronin, these traits include that the technologies are: "accessible, cheap, concealable, multi-use, easily combined with other technologies, and given to unexpected uses" (Cronin 2019, 257–58). This theory is useful because it provides a framework for understanding violent disruptive technology adoption based on a series of observable patterns and characteristics directly related to some of the *properties* of the innovations concerned. Furthermore, Cronin's work brings a much-needed focus to the *combinations* of emerging and disruptive technologies that are beginning to surface. Except for a large body of work focusing on the convergence of drones and Artificial Intelligence (Scharre 2018; Johnson 2020; Scharre 2019; Pedron and da Cruz 2020), wider consideration of various other disruptive technological convergences is somewhat lacking in scholarly work on drones. In this regard, Cronin importantly draws our attention to some of the implications of an emerging combination of drone technology with 3D printing and nascent autonomy. She importantly highlights their potential to "…interact with and build upon each other, enabling unexpected popular innovation…" (Cronin 2019, 202). This point is centrally around emergence, and it is an important one for our understanding of drones and their convergence with other technologies going forward. Bringing together multiple technologies will naturally introduce new capacities and capabilities, but they may be ones we do not

intend or have not considered. In such situations, we may not be equipped to respond to, or deal with, challenges arising from unexpected uses, effects, or applications. We have already seen the challenges of being unprepared and ill-equipped to deal with consumer, and indeed other types of drones playing out in conflict. The use of consumer drones by Daesh in 2017 in Syria and Iraq was an unexpected problem that, at the time, posed significant challenges for US-backed forces who were ill-equipped to deal with the issue (B. Watson 2017). Furthermore, the last few years have seen a flurry of drone related incidents at airports, often causing significant and lengthy disruption (European Union Aviation Safety Agency 2021, 4–5). More recently, we are still seeing the use of expensive missiles to take down inexpensive drones in conflict situations (Rudy Ruitenberg 2024) despite a plethora of innovations that are better suited to the job now existing (Holland Michel 2019). As drone technology begins to merge and be combined with other emerging and disruptive technologies, the potential to be surprised by either novel usage, or novel effects of these combinations is likely to rise. Cronin's major assertion around the combination of drones, 3D printing and autonomy hinges around the concept of extended reach; a concept with a long tradition in discussions around technological innovation and power projection as outlined in Chapter 1 (Cronin 2019, 202). Specifically, Cronin seeks to highlight the way in which multiple disruptive technologies are now amalgamating in unique ways and, as a result, offer this extension of reach to non-state actors. While Cronin's emphasis on convergence is of crucial importance to the drone discourse, her analysis stops short of exploring the wider or deeper implications and potential problems that might stem from such clusters of disruptive technology. Akin to Jackman, Cronin recognises various ways in which cheap consumer drones might be modified, but beyond the flexibility, ease of production, and extension of reach these modifications bring to their users, other aspects are overlooked. Principally, the complexity introduced by 3D printed drone parts to issues of regulation, traceability, and attribution are not considered, which is surprising. More broadly, Cronin's theory of lethal empowerment, while setting out a useful framework of characteristics for lethal diffuse technology adoption, fails to present a deep assessment of how these characteristics arise and manifest. The author herself notes that her work does not cover the technological capabilities and design of the technologies she discusses (Cronin 2019, 4). While this is understandable given her non-technical field, the resulting theory offers an incomplete reading of the attributes – and implications of those attributes – presented by the theory. By placing a more centred focus on *how* such attributes come to be, we can better illuminate the array of properties, both internal and external, that contribute to the construction (both technical and non-technical) of the traits Cronin outlines in her theory. Thus, we can begin to move from – *here are a series of traits we can observe* – towards a more granular understanding of how these traits come into being, what makes them, how they are exploited, what they enable, why they are effective, and the wider effects or implications their exploitation may give rise to.

Existing work on consumer drones and their capacity to be modified is limited. Both Jackman and Cronin, two voices at the forefront of discussions on consumer drones and their associated threats and risks, while offering important contributions to the drone discourse, leave vital questions unanswered and underexplored. To fully comprehend the scope of the drone's modification potential and its implications going forward, there is a necessity to unpack in greater depth both the ways in which emerging drone developments may evolve the drone beyond our current conceptualisation of it, and to understand how these potentials play into, and interact with, technology adoption, capabilities, and strategic effects. There is thus an opportunity to extend the existing – and nascent – literature on consumer drone modification through exploring in more depth how the drone's modifiability may give rise to novel forms of use and effect.

2.4 Conclusion

The discourse pertaining to drones in international relations and security studies is wide ranging. As discussed at the beginning of this chapter, this body of work has traditionally had a predominant focus on themes around the legality, practicality, ethics, and morality of targeted killing practices in the post-9/11 era. While these preoccupations are still a prevalent theme running through scholarship on drones, a slow shift is emerging against the backdrop of the rising production and adoption of consumer drones. The advent of consumer drone technology has given access to this technology to a wider range of actors on the international stage. Indeed, both state and non-state actors are utilising drones today with great effect in various contexts. While this shift in the discourse is still nascent, it marks an important departure from the previous first wave of drone literature. As we begin to see the use of drones become more fragmented among a wider array of both state and non-state actors, and as drones themselves become more complex and multiple in terms of their adoption, form, function, and capability, new areas of exploration are emerging. Indeed, these complexities raise new questions about drone use, implications and effects that are yet to be adequately explored within the international relations literature.

As previously noted, the drone is emerging as a device capable of generating confusion and deniability around its use. Important avenues of inquiry around agency and the drone's capacity to *create*, *enable*, or *produce* certain effects or conditions remain underexplored in the critical security studies and wider international relations scholarship. The pace of innovation and change in the realm of drone technology renders it a non-static device; one that is continuously changing whether in form, capability, or its purpose and context of use. Even rudimentary and simplistic drones can be used to facilitate deniable, destructive, and disruptive events. This ushers in questions around what is it about the drone and its use that enables such effects to be produced? And what does the future hold as science and technology drive the drone as we currently know it to new forms, effects, functions, and

contexts? These questions are underexplored in both International Relations scholarship and the wider drone discourse. Accordingly, this review has taken a thematic approach to explore literature across three areas relevant to this inquiry: consumer drone technology and its capacity to be modified; critical perspectives on drones and non-human agency; and the concept of ambiguity in relation to drone use. In so doing, this review highlights key gaps that exist in relation to each area and illuminates the value that can be added to the discourse on drones by bringing these three areas into dialogue with each other.

First, this review considered the ways in which ambiguity as a concept has been explored in international relations and in the context of the drone. Attention to the concept of ambiguity in international relations scholarship has, until recently, been limited to explorations of ambiguity in nuclear deterrence (Baylis 1995). This has begun to change in the past few years, as work pertaining to ambiguity and its role in hybrid war has come to the fore (Mumford 2020; Carlucci and Mumford 2023). Though this work makes important inroads into illuminating the importance of considering ambiguity as a stand-alone concept in conflict and war, beyond these two contributions, exploration of ambiguity in contemporary international relations is severely lacking. Importantly, this section of the review exposed the surface-level nature of existing inquiries into ambiguity in conflict, with authors treating the condition as a given, rather than seeking to unpack its constituent nature. This is echoed in the only existing study that attends to the notion of ambiguity in direct correlation with drone technology. Hwang's conceptualisation of the drone's role in generating ambiguity is limited to a narrow inquiry of the drone's lack of an operator and the capacity for it to be utilised by proxies (Hwang 2021). Furthermore, the approach is state-centric in approach, giving rise to critical oversights as to how different, non-human aspects associated with the drone and its use may combine and coalesce in such situations to contribute to the production of ambiguity. While Hwang's work marks an important step in the conversation about drones, and adds further credibility to a deeper analysis of the drone and its capacity to generate ambiguity, it falls short in its analysis overall. Indeed, what is it about the drone or its use that plays a part in the emerging ambiguity surrounding this device and its use? What factors contribute to the production of ambiguity, and what are the implications for international relations and security? Furthermore, it fails to take into account the changing nature of drone technology and the added complexities that consumer drones bring to this problem-space, highlighting a key gap that requires expansion.

Second, the review moved its focus to Critical Security Studies, reviewing works on drones which take into consideration non-human agency and drone technology. These perspectives foreground the role of non-human 'actants' and their capacity to shape, influence, or produce certain practices or 'things'. This body of work lays important foundations for how we can begin to understand the role of the drone in international relations and security today, as not only a tool capable of being used to

carry out the will of the operator, but as tools with the capacity to themselves produce and generate 'things' and effects beyond those for which they were initially intended. Grayson's work on 'excesses', in investigating what the drone might produce in excess of its intended uses, begins an important avenue of exploration which is yet to be fully explored to its full potential (Grayson 2016b). Since Grayson's seminal perspective on this area, the literature remains devoid of meaningful explorations into the production of novel effects by drone technology as they transcend immediate operator intentions. Furthermore, the literature on drones within CSS does not wholly attend to the changing and evolving nature of drone technology. With the exception of works taking into consideration the advent of artificial intelligence and what this means for security and conflict from critical perspectives, there remains a surprising deficit into exploration of the drone's modification and adaptable potential. This opens up a crucial gap where material-oriented approaches within CSS could assist in revealing much more about the contemporary drone, its non-static nature, and what this means for the international.

Finally, this review attended to key literature emerging amidst the context of the increasing production and adoption of consumer drone technology by a multitude of actors on the international stage. The advent of consumer drone technology has marked the beginning of a much-needed shift in the drone discourse, to work less preoccupied with targeted killing, and with more focus on the nuanced implications of drone technology, its accessibly, and its modifiability. This body of work is nascent given the relative recency of the widespread adoption of consumer drone technology and the emerging nature of the implications surrounding their use. Accordingly, this part of the review focused on two key voices whose work is valuable to evolving the discussion on drones as the technology itself, and the ways it is used, continues to change. Jackman's work on the modifiability of consumer drone technology, while originating from the discipline of human geography, makes an important contribution to the discourse on drones within the context of defence and security. Her work argues for an understanding of consumer drones that pays closer attention to the technology's malleable nature. She furthers our current understanding of the consumer drone through an exploration of industry innovation in the consumer drone space, experimentation by hobbyists, and the evolving airspaces in which drones are used. In so doing, Jackman calls for wider consideration of the drone's capacity to be modified, altered, and put to novel use in addition to the opportunities and threats that may come from this (Jackman 2019, 377). Furthermore, this section considered Cronin's theory of lethal empowerment, which marks another important contribution to our understanding of drone use in the consumer drone era. Her work makes the case that certain technologies are more attractive to – and thus more likely to be widely adopted by – non-state actors than other technologies based upon a series of attributes or qualities those tools and technologies have. Her theory outlines these attributes, yet the analysis falls short of unpacking how such attributes come to be. This critical absence renders Cronin's theory one that presents an incomplete reading of the attributes that form it.

Both contributions from Jackman and Cronin begin important threads of discussion pertaining to consumer drone modification and evolution that require further elucidation.

Overall, this review exposes fundamental gaps in our understanding of the drone and the implications of its continual evolution and transformation in relation to the effects it can produce. Importantly, this review highlights the latent potential in bridging the gap between conversations around drone evolutions and modification, the drone's capacity to produce or generate novel effects or 'excesses', and discussions around the production of ambiguity in conflict. It is at this crucial intersection that there exists an opportunity to contribute to the ongoing drone discourse within Critical Security Studies, bringing these three areas into dialogue. Where the literature has thus far fallen short, is in a critical failure to wholly attend to the transformations that drone technology are undergoing and what this might mean for security and conflict going forward. Attending to this is important for being able to comprehend the emerging security threats associated with drone use as the technology continues to transform to new forms, capabilities, and functions. Unpacking in detail what the drone's evolution and modification potential presents for defence and security is necessary and yet underexplored within CSS and International Relations literature more broadly. Drawing on thinking that decentres our focus from traditional state-centric perspectives on drones and their use holds promise for undertaking such an exploration. Certainly, the materiality of drone evolutions and its role in shaping the international is yet to be meaningfully unpacked. Embarking on an exploration of both intrinsic and extrinsic factors surrounding drones and the phenomenon of ambiguity may help us to identify and unpack how disruptive technologies – such as the drone – can be leveraged as a mechanism to increase ambiguity in the contexts within which they are used. Ambiguity, as outlined in Chapter 1, is a long-standing feature of conflict and war. This is not new. However, establishing how new tools and technologies utilised within conflict might exaggerate or frustrate such conditions is vital to ascertaining a deeper knowledge of what makes certain tools attractive. It is here that an essential, material dimension is overlooked in frameworks such as Cronin's theory of lethal empowerment, which, while identifying traits that make certain technological tools attractive, fails to identify or unpack how these traits are produced. Moreover, they fail to consider the assemblages of wider components or factors that coalesce or combine to afford these attributes. These half-readings give us little control over our understandings of what is happening and why. Without this dimension, we are consigning ourselves to a future where we submit to the effects of technology as something that is imbued, unavoidable, or a given, rather than equipping ourselves with knowledge around how these effects are constituted and what makes them effective. Such knowledge, in turn, can help us be better placed not only to understand what is occurring and why, but can also assist in better responses and decision-making, mitigation or defence.

The tendency within the study of the drone within CSS has been to precisely *not* focus on the technology itself, rather to assess only the factors that connect to, contribute, or sit around the technology to elucidate meaning about it and its broader politics. Yet as others have demonstrated, and as this review makes clear, properties intrinsic to material objects play a part in the active shaping of the social world and the international. In the same way, by purposefully considering the properties that make up the device we know as the drone, we stand to learn more than we know already. The drone is an object both physical and digital, comprising a vast array of 'things' that make it what it is. Indeed, by interrogating the object itself, we can bring to light new avenues of exploration in relation to the broader array of factors that 'make' the drone what it is and make it capable of the effects it can 'produce'. As many of the works on drones within CSS reviewed here highlight, different knowledge gets produced about the same 'thing' (the drone in this case) depending upon how one studies it, and which aspects are foregrounded in the analysis. This thesis is therefore interested in uncovering the constitutive part drones play in the phenomenon of ambiguity in conflict and security settings. While ambiguity itself is not a new phenomenon, what *is* new, are the emerging ways and means through which ambiguity might be created, heightened, or exploited. Does the drone and its inherent materiality play a constitutive part in the production of ambiguity both in conflict and beyond it? In bringing the drone and the condition of ambiguity into direct dialogue with material-oriented perspectives within CSS, our understandings of drones and their unfolding utility in subthreshold conflict can be elucidated. If we can understand how it manifests, we can – in theory – begin to think about how to disambiguate the drone and its use. In wielding the capacity to produce, as Mumford puts it, a cognitive impasse, we must then attend to the notion of agency in relation to the production of ambiguity (Carlucci and Mumford 2023). Where does the drone's capacity to *produce* ambiguity come from (if it *itself* indeed has that capacity)? There is much to explore here to glean deeper understandings of the use of drones in and beyond the context of conflict. Deepening that understanding of this technology now, is more pertinent than ever given the rising adoption of drones across both civilian and military spheres, and the range of actors with access to them. By taking a focus on the parts and components, we can uncover further factors that play a role in the production of ambiguity.

Following calls for greater consideration of the drone's capacity to be modified and the threats this may pose, coupled with its potential capacity to produce effects beyond those initially intended, there is a necessity to elucidate the underexplored dimensions of the drone's modifiability and adaptability within the Critical Security Studies literature. Indeed, the drone discourse both within and beyond CSS remains bereft of any such comprehensive investigation. This is a conspicuous oversight; perhaps symptomatic of the continuing preoccupation with analyses on drones and their role in targeted killing and subjectification of populations through legal and ethical lenses. Indeed, even works attending to certain evolutions in drone technology such as the integration of artificial

intelligence, predominately still fall into this latter category. Attending to this gap can assist in bringing to light new ways in which we can observe complex socio-technical systems such as the drone shaping the international through the effects it can produce. Such an investigation would add to ongoing discussions within CSS which seek to challenge traditional state-centrism in security studies, arguing for more nuance understandings of the drone's capacity to give rise to novel modes of influence and effects that in turn may shape how these devices are used, perceived, and even designed.

3 Methodology

This research takes an inductive qualitative research approach to gain a deeper understanding of ambiguity as it pertains to drone technology. As an underexplored phenomenon in the context of drones yet one we are increasingly seeing emerge around drone use, establishing a comprehensive understanding of how the condition of ambiguity manifests in relation to the drone is necessary. In collating, reviewing, and analysing existing data around contemporary drone usage using a rigorous method, the work seeks to shed light on this phenomenon in a data-driven way. To do this, the research takes a systematic approach to data collection, applying Reflexive Thematic Analysis to identify themes and commonalities across data using a structured process. This approach allows for a clear view of the different ways in which we can observe ambiguity manifesting in relation to the drone in a way that allows for interpretation that remains grounded in appropriate data. This work is positioned within Critical Security Studies, drawing on New Materialist thinking to inform the analysis and interpretation of findings. This approach offers a new lens through which to consider the phenomenon of ambiguity as it relates to drone use in contemporary security and conflict contexts. Moreover, it provides a coherent mechanism for gaining a deeper understanding of how the drone's intrinsic properties - non-human factors – play a role in the production of ambiguity around their use.

This chapter sets out the rationale for the approach and methods utilised throughout this research. In addition, it outlines the theoretical framework guiding aspects of both the project's design, and the interpretation of its findings – New Materialism. It begins with an overview of the research design underpinning the work (3.1). It then introduces the new materialist framework guiding aspects of the research process, data analysis, and interpretation (3.2). It sets out the suitability of New Materialist thinking for a project of this kind, with key emphasis on its advantages for studies with a focus on non-human objects, and their relational dynamics with human and other factors. Discussion then moves on to outline how data was collected (3.3), including key considerations pertaining to the use of extant data and secondary sources, which form an integral part of the data collection for this work. This is followed by discussion of the chosen method of data analysis – Reflexive Thematic Analysis (3.4). It provides examples of how the processes and procedures of this method are followed during the research process (3.4.1) and outlines how the integration of thematic analysis with new materialism is approached (3.4.2). Subsequently, ethical considerations relating to the conduct of research are presented (3.5), followed by an outline of limitations affecting the study (3.6) and concluding overview (3.7).

3.1 Research Design

This project's research design integrates Thematic Analysis with New Materialism, leveraging the strengths of both to explore and expose patterns, relationships, and interactions underpinning or driving the phenomenon of ambiguity as it pertains to drones and their use. The nature of the problem-space being explored is complex, involving interconnected dimensions. Specifically, these are the emergence of ambiguity around aspects of drone use (such as deniability and anonymity), the evolving nature of drone technology and its role in amplifying ambiguity, and the capacity for drones to generate novel modes of influence and effect, with a focus on the production of ambiguity. This complexity requires an approach that can provide the necessary depth to understand the material and relational dynamics that may be at play across these dimensions. The utility of bringing together thematic analysis and new materialism for the exploration of this problem-space is visualised in Figure 3.

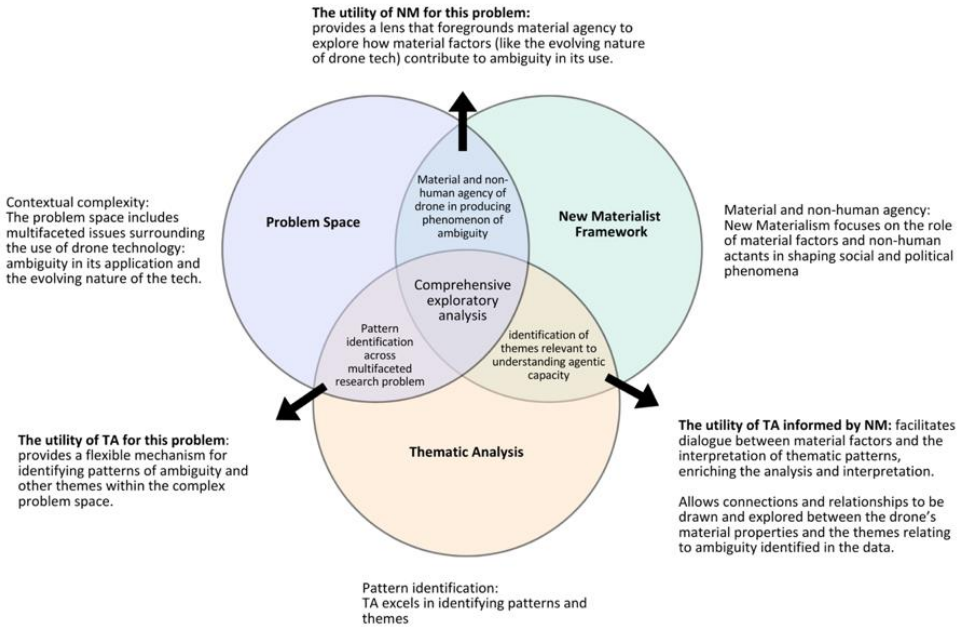

Figure 3. Venn Diagram showing the intersection of the problem space, theoretical framework, and method of analysis.

3.1.1 Research Objectives

The objectives of this research are to ascertain a deeper understanding of the phenomenon of ambiguity around drone use. We can observe the use of drones in increasingly ambiguous situations and utilised by ambiguous actors. This is occurring against the backdrop of an ever-evolving landscape of drone technology as it continues to shift to new forms and functions, and as more actors gain access to the technology in both the civilian and defence contexts. The work seeks to investigate

these intersections to understand the dynamics and components at play in the phenomenon of ambiguity around drone use. The central research objectives developed for, and guiding this study are:

1. To explore how ambiguity relates to drone use, and to understand what role the material and relational capacities of drones might play in creating, mediating, or amplifying ambiguity.
2. To analyse how the evolving nature of drone technology is reconfiguring the form, function, and practices of drones and their use, and how these changes interact with ambiguity.
3. To investigate how the cyber-physical properties of drones interacts with ambiguity, and how these entanglements may amplify ambiguity in security and conflict settings.

These questions formed the starting point for each central research chapter in this work. The research is designed in three distinct, yet interconnected phases across three core research chapters (Chapters 4-6). Each of these chapters focuses on a specific research question (RQ1, RQ2, and RQ3, respectively) and involves the collection and thematic analysis of relevant data. The main content within each core chapter presents and discusses the themes found through the thematic analysis and explores their implications for the overarching research. This design allows for a richer output and depth of analysis than could be achieved trying to conduct one single thematic analysis attempting to cover each facet of the problem space. Findings from each chapter are subsequently discussed in relation to each other, identifying connections, relationships, and dynamics between them. The approach taken facilitates a nuanced exploration of each facet and contributes uniquely to the drone discourse by bringing these areas into dialogue in a way that has not been done before. The conclusion will include an evaluative section assessing the efficacy of this approach and any challenges it presents for the conduct of the research.

The next section outlines in more detail the theoretical framework guiding facets of the research, followed by details of the data collection and data analysis method.

3.2 Theoretical Framework: New Materialism

At the heart of this research is an exploration of drone technology, its emerging interaction with the phenomenon of ambiguity, and the dynamics of this interaction in relation to those utilising them, perceiving them, and the environments within which they operate. Part of this is a focus on the drone itself as an object, to understand how its material facets such as evolving nature, configuration, and technical components play a role in shaping the effects it can produce. New Materialism is an approach to social inquiry that de-centres human agency, concentrating instead upon how configurations of human and non-human things come together in “assemblages” which produce certain things or phenomena (N. J. Fox and Alldred 2015, 399). In bringing material factors to the fore, new materialist approaches pay critical attention to non-human agency and consider a re-

thinking of matter – and its role – integral to the comprehension of contemporary social issues (Coole and Frost 2010, 2). As such, New Materialism offers a useful lens through which to approach this exploratory work as it foregrounds the drone as a material artefact, allowing for an inquiry that moves away from human-centric analyses to reveal new insights. This section presents a background overview of New Materialism, specifying the key thinkers whose approaches to new materialism inform this research. It then outlines the suitability of New Materialism for the study, including a consideration of other works which have successfully approached the subject of the drone through a new materialist lens.

3.2.1 Background: New Materialism

New Materialism emerged in response to anthropocentric social inquiry, yet materialism itself has a long tradition (N. J. Fox and Alldred 2015, 400). Many new materialist approaches draw on what some have termed the 'old materialist' thinking of Marx, Deleuze and Guattari, and Spinoza (Coole and Frost 2010). The new materialisms emerged with a renewed focus on the role of non-human things in making up the social world. The contemporary theoretical framework of New Materialism has since been adopted across various disciplines such as philosophy, politics, and international relations. It provides unique ways of studying and thinking about the agency of objects, allowing us to expose and explore the interactions and relationships between inanimate 'things' and humans. At the heart of this effort is thus a deep challenge to the traditional centrality of the human in modes of analysis (N. J. Fox and Alldred 2015, 399). By enabling us to acknowledge the significance of non-human things, new materialism broadens our perspective with regard to how things shape and play a role in the construct of our world and its many practices and phenomena.

Various frameworks for the study of objects have been established from the intellectual drive to better understand the role of non-human and inanimate things around us and how things may overlap, interconnect, and converge in ways not immediately evident. Indeed, assemblage thinking posits an influential conceptual framework for doing just that. Heavily rooted in the thinking of Deleuze and Guattari, assemblage thinking presents the concept that different phenomena are created or produced through heterogenous groupings of 'things' (assemblages), which coalesce temporarily to produce something (Guattari and Deleuze 1987). This way of thinking has a distinct focus on the complex dynamics, interactions, and contingency of 'things' that make up our world. As Curtis and Acuto point out, Deleuze – taking inspiration from developments in scientific thought such as emergence and non-linear dynamics – paved the way for what they describe as: "a way of conceptualizing the various entities of the natural and social world as assemblages of heterogeneous components that are always transient and open, and in process, never solidifying into a closed totality or system" (Acuto and Curtis 2014, 5). Deleuze and Guattari influentially set in motion the core idea that reality is

constituted of non-static, continuously changing arrays of components, both material and immaterial (Guattari and Deleuze 1987). This idea became a foundational one for thinkers such as Latour and DeLanda, whose work on Actor-Network Theory and Assemblage Theory respectively built on these ideas and further refined them (DeLanda 2006; Latour 2007).

Bruno Latour's enquiry into the 'missing masses' from sociological enquiry laid some of the key foundations for the development of new materialist thinking. Through a series of examples, he powerfully demonstrates why the material and physical things that make up our world – often unassuming, benign, or mundane – hold significance for social inquiry (Latour 1992). In what can only be described as a feat of passionate intellectual persuasion, he expressively argues that in order to produce a well-balanced account of society, we need to pay greater attention to the ways in which artifacts and the non-human play a role in shaping the world. He notably highlights that at the most basic level, if we want to understand the significance of non-human actors in constituting and shaping things, we have only to "imagine what other humans or other non-humans would have to do were this character not present" (Latour 1992, 229). He subsequently weaves a convincing problematisation of sociology's humancentric ways:

> "You discriminate between the human and the inhuman. I do not hold this bias (this one at least) and see only actors – some human, some nonhuman, some skilled, some unskilled – that exchange their properties."(Latour 1992, 236)

This central idea, of non-human and human entities being treated equally in an analysis of the social world came to form a central part of the influential Actor-Network Theory (ANT). The theory posits that to successfully understand something we encounter (a system), we should consider all components of that system regardless of whether they are human, technological, natural or artificial; each component is considered an *active member* of that system that interacts or intersects with other members (Latour 2007). This theory has been influential across a wide range of disciplines, from its origins in Science and Technology Studies (STS), to fields such as Environmental Studies, Cultural Studies, Political Science, and Geography.

The work of DeLanda, while acknowledging that objects may play a role in agency, sees agency in relation to objects slightly differently than Latour and other scholars at the forefront of ANT and its development. Rather than individual objects themselves having agency, DeLanda's approach regards agency as *distributed* across the various 'parts' or components of an assemblage. His emphasis rests on ideas such as emergence, complex systems, and the capacity for material or non-human things to self-organise. As Muller and Schurr note, there are many similarities between assemblage thinking and ANT (Müller and Schurr 2016, 217). Indeed, other scholars draw upon aspects from both approaches in thinking about objects, Jane Bennett's work on 'thing-power' and her broader concept

of ‘vibrant matter’ is a case in point. For Bennett, regardless of whether human or non-human, *matter* possesses a ‘vitality’ and agency that play an active role in the shaping of the world around us (Bennett 2004). This perspective argues for a consideration of all things as *active* rather than passive. She introduces the concept of ”thing-power” within her overarching framework of vibrant matter which encapsulates this active role of things in a powerful way. Thing-power refers to what Bennett describes as the “…curious ability of inanimate things to animate, to act, to produce effects dramatic and subtle” (Bennett 2004, 351). While Bennett draws on a range of theoretical ideas and philosophies in the development of these concepts, she draws particularly on Latour’s emphasis on the agency of objects, Deleuzian-Guatarrian thinking on immanence, contingency and the dynamic nature of the assemblage, and DeLanda’s closely aligned ideas about self-organisation (Bennett 2004). In the context of ‘thing-power’, she hones in on the notion of contingency, delineating the power of ‘things’ *as a function* of contingent factors:

> “…a material body always resides within some assemblage or other, and its thing-power is *a function of that grouping.* A thing has power by virtue of its operating in conjunction with other things.” (Bennett 2004, 354)

This idea, that the agency of things is the *property* of an assemblage is powerful. It foregrounds the Deleuzian-Guatarrian notion that phenomena are *produced through* heterogenous groupings, specifically linking that grouping to the capacity of things to act upon us (Guattari and Deleuze 1987). As Cudworth and Hobden highlight, Bennett argues for the recognition of inanimate matter and the role it plays in “affecting and configuring situations and events” (Cudworth and Hobden 2013, 445). Bennett’s way of seeing object agency as a *force exercised* by something, or some array of things, strikes a chord. The notion of a ‘force’ denotes a complex webs of activity, invisible action exerted quietly and occurring among, between, and through all manners of matter. Her overarching framework of vibrant matter brings this notion to conceptual life. Bennett’s ensuing exploration of the vitality of the inanimate and the non-human engages Deleuze’s ideas about the interplay of dynamic forces in the world and the multiplicity of assemblages. For Bennett, we can understand all matter as having an inherent agency and *vitality*. She argues that ‘things’ are not merely passive, they do not simply exist lifelessly, rather they possess a liveliness, an agency that can exert influence in the world (Bennett 2004, 365).

This research takes influence from Bennett’s thinking, approaching the concept of matter and agency from a vital materialist perspective. The research seeks to understand the role drone technology plays in relation to the phenomenon of ambiguity in conflict. In this context, interest lies in establishing if and how the drone holds the capacity to act, or produce the effect of ambiguity, and what wider grouping of things sits around this to enable that ‘force’ to be exercised. If there is ambiguity arising in relation to the drone and its use, what is this ambiguity a function of? What broader array of things

sits around the object of the drone (or its use) that produces ambiguity? This is something that has not been explored and it is a crucial gap this work seeks to address. Therefore, new materialism provides a suitable theoretical framework to explore this.

3.2.2 Drones and New Materialism

New Materialism has been increasingly embraced within International Relations and Security Studies scholarship, shifting perspectives away from analyses that are solely human and state-centric and towards an understanding of the agency of material things in the global arena (Srnicek, Fotou, and Arghand 2013, 397; M. B. Salter 2015). Indeed, new materialist perspectives challenge the various human-centric presumptions inherent to much classical international relations theory (Srnicek 2017). In this way, the significance of non-human things is brought into the analysis of how our worlds are constituted. Drone technology, a technology now widely adopted across many sectors of society, civilian life, and military institutions across the globe, has become an interesting empirical site for materialist perspectives and analysis to flourish in recent years. New Materialist approaches to the study of drones and their use have provided insightful expositions of various aspects of drone use and their broader implications for society at both the domestic and international levels. It is beyond the scope of this section to give an overview of these literatures (see section 2.2 which outlines key new materialist studies on drones within critical security studies). However, it is important from a methodological point of view to highlight that new materialism has been used effectively in various ways by scholars to understand aspects of drone technology and their implications (Meiches 2019; Grayson 2016b; 2016a; Kaplan 2020; Walters 2014). As an approach that places emphasis on the agentic capacities of non-human entities, their relational dynamics with humans and other 'actants', and their interactions, new materialism offers a useful lens to approach the complex socio-technical device that is the contemporary drone.

3.3 Data Collection

Data for this research took the form of documents, articles, academic texts and other grey literature. As a result of the Covid-19 pandemic, data collection methods for this research had to be revised. Where initial plans for interviews and workshops with individuals from the civilian, defence, and scientific communities became untenable during 2020-2021, the focus of data collection necessarily shifted to desk-based methods. The use of existing (or extant) documents and texts thus became central to this research. Extant texts refer to existing texts and documents produced outside of the research undertaking, yet relevant to that research undertaking (Ralph, Birks, and Chapman 2014, 3). A key advantage of utilising extant data is that it has not been subject to influence by the researcher, however, it is fully acknowledged that *interpretation* of extant data may still be subjective (Charmaz 2017a, 2). The use of extant texts is apt for research endeavours where study of the events cannot be

directly observed (Bowen 2009, 31). For the present research, this is the case both in relation to the nascent and emergent nature of the phenomenon under study, and due to limitations on fieldwork due to the Covid-19 pandemic.

While it has been noted that the overall advantages of document analysis as a form of data collection significantly outweigh any potential limitations, a few potential limitations do exist and are outlined well by Bowmen (Bowen 2009, 32). The three main possible limitations he identifies are: limited detail provided by documents; potential low retrievability; and possible biased selectivity. Of these possible limitations, biased selectivity is a potential issue and one that is duly considered throughout the data selection process. Biased selectivity refers to the context from which a document has arisen, where they may be likely to be positioned in line with the agenda or policies of the organisation where it was produced (Bowen 2009, 32). An emphasis on reflexivity is therefore crucial. Being cognizant of the context from which selected documents have arisen has thus become a core tenet of the data selection and reflexive process throughout this research.

3.3.1 Data Collection Process

Extant texts were collected using online database searches following a systematic approach as carried out in a systematic literature review (Nightingale 2009). Searches were implemented using well known databases including Google Scholar, IEEE Xplore, Elsevier, and Scopus. Further searches were conducted to capture non-academic texts and articles through news websites, international organisation publication archives, and defence and security magazines. Terms used within searches were tailored in accordance with the relevant research questions. For example, building on findings from Chapter 4, Chapter 5 sought to understand what properties give rise to the adaptable nature of drone technology, and to explore the nature of interaction between the drone's adaptability and the condition of ambiguity. Terms used in string searches for this part of research included words such as "ambiguity", "adaptability", "modification", "repurposing", and a range of terms commonly used in association with drone technology (drone, UAV, UAS, unmanned aerial vehicle, unmanned aerial system). After initial searches, search terms were reviewed for accuracy. Texts retrieved from this process contained a mixture of academic journal articles, book chapters, conference papers, news articles, magazine articles, technical reports, marketing materials, and white papers. The purpose of going beyond a search of academic literature was to ensure a rounded dataset with material derived from multiple sectors. Furthermore, due to the nascent nature of the phenomenon under investigation, it was necessary to look beyond academic texts to also include other emerging discourses on drones outside of academia. Naturally, these searches produced hundreds of results which had to be refined. Searches were refined using filters where available to specify hits by relevant field or topic and refine the number of results. Titles and abstracts were reviewed for their relevance to the research questions,

with a similar review process used to assess relevance of other grey materials and other non-academic materials. The exclusion criteria included texts published in unrelated fields, duplicate entries to avoid redundancy, low quality content, content requiring translation, and outdated material. The same process was applied for each of the three core research chapters (Chapters 4-6). Selected texts were then saved for further analysis, details of which are outlined in the next section.

3.4 Data Analysis: Thematic Analysis

The method for analysis being used in this research is Thematic Analysis (hereafter TA). TA is a qualitative research approach with a focus on the identification of themes from across a dataset. While there are different versions and approaches to TA, the approach taken in this work follows Braun and Clarke's Reflexive TA, which places emphasis on acknowledging the role of the researcher in how data is interpreted and how themes are constructed (Braun and Clarke 2021). Reflexive TA is appropriate for this research over and above other forms of TA due to its flexibility and incorporation of the researcher's theoretical stance and subjectivity, which are acknowledged as an integral component of the analysis (Braun and Clarke 2021, 298). This is important for this work, where theoretical concepts from new materialism inform aspects of the analytical process.

Reflexive TA can be applied inductively, deductively, or in combination depending on research design. This research uses a combined approach, approaching the initial coding inductively to identify data-driven patterns within the data, before shifting to a more deductive analytical approach to analyse possible themes. The 6-step process followed throughout the TA was that outlined by Braun and Clarke, involving: data familiarisation; initial generation of codes; identification of themes; reviewing themes; defining and naming themes; and writing up the findings (Braun and Clarke 2012). These steps were followed during analysis of data for chapters 4-6. More detail is outlined in the next section.

Reflexive TA was chosen for this work due to its capacity to identify multiple patterns across a dataset that are tangibly grounded in evidence from that dataset, while also allowing enough flexibility for interpretation that is informed by other theories or concepts. Thus, while still involving elements of interpretation on behalf of the researcher, adhering to the TA process allows for interpretation to be evidence-based, data-driven, and supported by a rigorous and structured process. It is important to note that TA is not the only rigorous qualitative method that could have been chosen. Grounded Theory is another data-driven and evidence-based approach. Specifically, Constructivist Grounded Theory offers a similar level of flexibility that could have been a good fit for the work (Charmaz 2017b; 2017a). However, due to Grounded Theory's emphasis on theory generation, it was not suited to an exploratory study of this nature. TA is more suited to exploratory

studies seeking to understand the landscape of a possible phenomenon, rather than generating a theory about a well understood one. TA thus provides an appropriate analytical mechanism for obtaining a foundational understanding of the various ways we might observe ambiguity in relation to the use of drone technology, as this study sets out to do.

3.4.1 Coding Process and Analysis

An integral part of the TA process involves coding the data that has been collected for analysis. Coding in this context refers to the line-by-line analysis of text to identify excerpts from the data relevant to the research (Braun and Clarke 2012, 61). An inductive open coding strategy is adopted to allow for as much insight to be gathered from the data as possible. Inductive open coding strategies do not pre-define codes prior to the coding taking place, rather, they allow for codes to be created as the data is analysed in line with what is found (Braun and Clarke 2012). Coding can be done manually using spreadsheets and colour coding, or by using software. In this case, the qualitative software analysis tool NVivo will be utilised to manage the large datasets being analysed. This tool allows you to highlight and separate out specific excerpts of text relevant to the research, keeping them organised. An early example of coded text from one report during analysis of data in Chapter 4 can be seen in Figure 4 as an illustrative example.

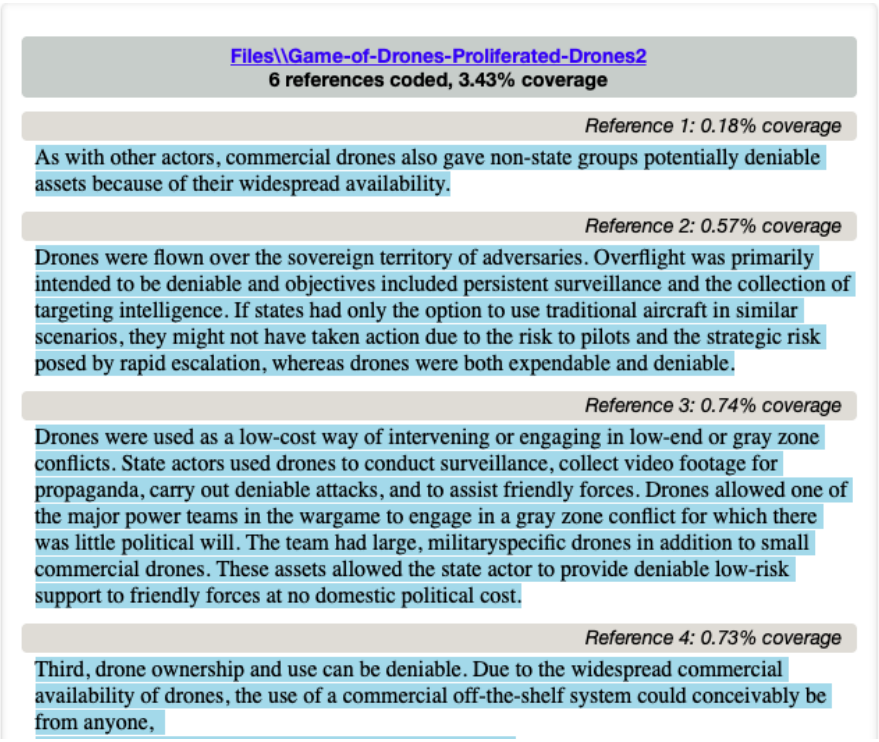

Figure 4: NVivo Coding example showing excerpts highlighted that relate to ideas around drone deniability.

Following the method outlined by Braun and Clarke, the researcher then designates excerpts with a descriptive label or 'code' to represent them in the database. In the example shown in Figure 4, the highlighted excerpts were coded against the label 'deniability' and any other relevant codes where relationships or associations with deniability are identified in the text (e.g. 'widespread availability' is frequently mentioned in colocation with discussion around deniability). This approach allows you to begin seeing associations between things in the data which may later help you derive themes. Codes are continually reviewed for relevance and overlap and where two or more codes refer to the same thing under a different name, they are merged (Braun and Clarke 2012). Related codes can be nested within NVivo as 'parent' and 'child', allowing for a clearer picture of how codes relate (see visualisation in Figure 5). As codes accumulate, the researcher begins identifying overarching themes that link them together. After the initial inductive identification of themes, the mode of analysis takes a more deductive orientation. This involved reviewing and refining themes by looking specifically for instances or patterns within the coding influenced by key new materialist concepts. These included identifying instances where agential capacities, affordances, or relational dynamics may be at play. This analytical strategy is positioned within a constructionist orientation, aligning with new materialism and encompassing the strengths of both inductive and deductive reasoning. Theme identification from the data is not viewed as an essentialist process in which themes 'emerge' from the data, but rather as a constructive process – where themes are produced through active interaction with the data, informed by the theoretical lens of new materialism applied.

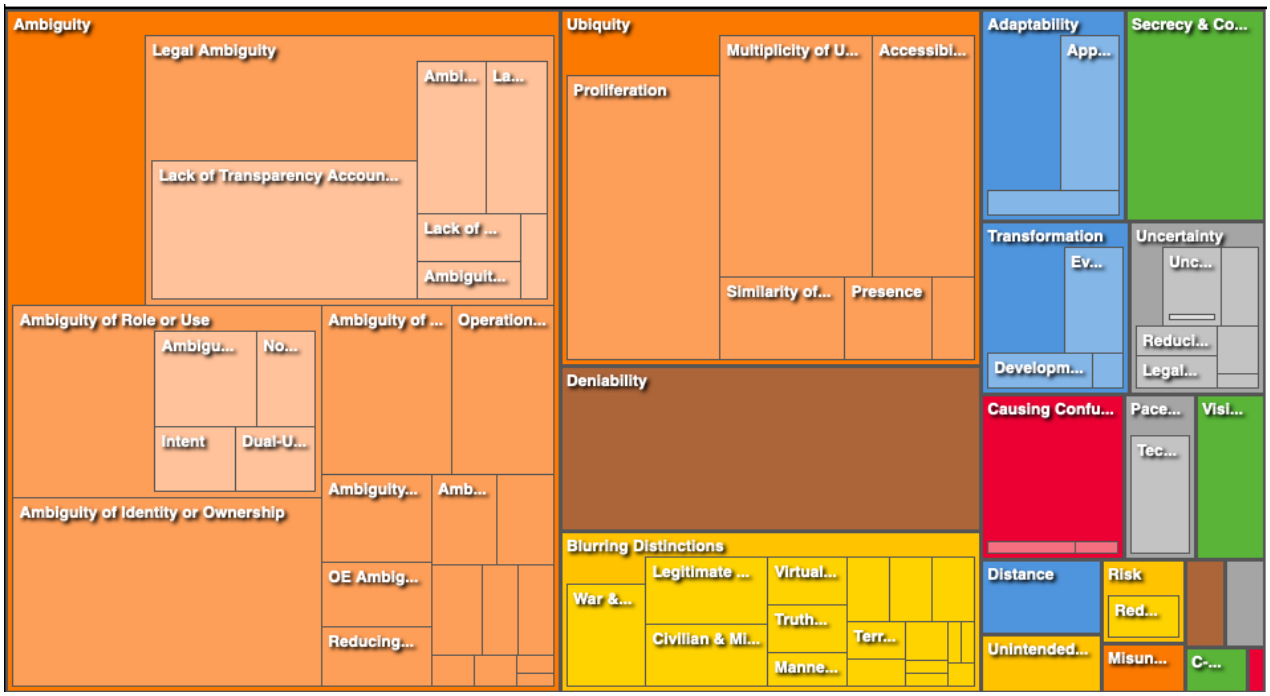

Figure 5. Visualisation of nested coding from data analysis in Chapter 4.

3.4.2 Integration of Theoretical Framework

The reflexive TA carried out in this research is informed by new materialist thinking, as outlined in section 3.2. This integrated approach aims to facilitate a richer landscape of interpretation. Through TA, the aim is to identify and capture recurring themes in the data that highlight concerns around, or instances of, ambiguity pertaining to drones and their use and aspects contributing to this phenomenon. Findings are analysed and discussed from a new materialist perspective to identify the agential capacities, affordances, and relational dynamics at play. This approach allows for an exploration which foregrounds a material consideration of drone technology (such as its physical composition, digitality, and evolving nature) and their interactions with patterns of ambiguity found in the data.

Studies using similar integrated approaches, where thematic analysis is informed by new materialism can be found in various subject areas, with a large number within the digital health, and health and social studies (Vardeman et al. 2024; Lupton 2020; Maslen and Lupton 2020; Lupton 2019; Flynn and Feely 2023). These studies demonstrate the utility of this approach for exploring the interplay between material and non-material subjects across a range of identified themes relevant to the research. Utilising insights from new materialism, Vardeman et al foreground material agency in their interpretation of themes to effectively examine the entanglement between digital platforms and physical bodies. In doing so, they bring to light some of the impacts this interplay has on both material and discursive practices in the health sector (Vardeman et al. 2024). Using a new materialist lens in conjunction with thematic analysis offers a comprehensive exploratory analysis that can successfully capture complexities in a multifaceted problem space. In taking this approach, this research seeks to shed new light on the phenomenon of ambiguity as it pertains to the drone by interrogating the array of material components, configurations, and dynamics playing a part in its production.

3.5 Ethical Considerations

Ethical considerations are a vital component of undertaking any research project. Indeed, it is integral regardless of whether direct participants are involved in the study. While this research does not involve direct participants, there are still ethical considerations to factor in, particularly in relation to the subject matter under exploration which has potential practical applications across both defence and offence within the context of drone use in ambiguous conflict domains. This section outlines the ethical considerations guiding this work to ensure it remains grounded in a robust ethical framework throughout the whole lifecycle of the project, from the data collection process, and interpretation of the findings, to the wider dissemination of the outputs.

3.5.1 Methodological Integrity

The proper use of methods is paramount to the conduct of rigorous and transparent research. Applying methods in a study requires following a particular process, and as some scholars highlight, researchers must adhere to chosen methods fully and not selectively in order to maintain integrity of the methodological approach (Corbin and Strauss 2014, 13). Different variations of methods such as TA offer varying levels of flexibility in how the method can be applied (Braun and Clarke 2021). Ensuring clarity and transparency over the approach adopted is important to set a clear context for how a method is applied in the work. To ensure the present research maintains methodological integrity, Reflexive TA as outlined by Braun and Clarke is adopted and adhered to. Moreover, as with any method involving aspects of interpretation, reflection on how findings are interpreted is integral. The choice of reflective TA allows for an awareness of the researcher's role in the shaping of the findings throughout the project, which is especially important for this work. Maintaining methodological integrity assists in ensuring findings are credible and that interpretive aspects of the analysis are grounded in the data and within the study's wider ethical framework.

3.5.2 Sourcing of Data

This research involves the sourcing and collection of secondary sources – or extant data – relevant to the research aims. Ensuring sources are ethically sourced, reliable and of high quality to reduce bias in the dataset is paramount. Steps taken to mitigate potential bias include reviewing sources for reliability; triangulating sources to cross-verify information to ensure credibility; ensuring academic texts utilised have gone through the peer review process; ensuring data diversity by collecting materials from a variety of sources such as academic texts, government publications, technical reports, industry reports, and reputable news outlets; and critical appraisal of sources to understand their purposes of production, intended audience, funding, and politics.

3.5.3 Dissemination and Output

Ethical considerations also extend to the output of the research and dissemination of findings. It is important to be cognizant of the broader implications and potential applications of any research. The primary objective of this research is to advance knowledge around the problem-space, contributing to the disambiguation of drone use, while informing the discussion on the future of drone use and guiding the discourse towards more responsible use in contexts that lack clarity. However, it is recognised that the findings could be applied in various contexts within the context of drone use in ambiguous settings. This work thus acknowledges the importance of transparency around its

objectives, methods, and findings. It maintains an open and clear communication of the research purpose and scope to mitigate misapplication of the findings generated.

3.5.4 Research Standards and Funding

Alongside ethical considerations regarding methodological integrity are ethical considerations relating to the funding body and research standards. This project is funded by the Economic and Social Research Council (ESRC). As such, the quality of this research strives to achieve a certain standard congruent with the reputation of the ESRC and the high-quality research it supports. It follows the ESRC research ethics guidelines to ensure this work is carried out to these high standards, adhering to key principles to ensure ethical conduct throughout the lifecycle of the project (UKRI 2023). At the same time, it is vital to ensure the research remains independent and unbiased, irrespective of any funding sources. Thus, maintaining objectivity, attending to methodological rigour, and striving to produce the best results possible grounded in a robust evidence base, ensures the work upholds the ethical standards and responsibility surrounding the research.

3.6 Limitations

As with any study, it is important to acknowledge any limitations that may affect the study's scope, conduct, or findings. The main limitation of this study relates to the temporal constraints of the data collection and analysis process. This is outlined here to provide context for the findings and to ensure the scope of the study is clear. Data collection for this work took place largely between 2020-2021. Consequently, the datasets on which thematic analysis was conducted for each core chapter include data up to this period. This means the datasets do not include materials that account for events and developments after this time. However, discussion pertaining to recent global events is incorporated where appropriate outside of the TA process in later stages of the work. While this does not impact the findings of this work or undermine their validity, it does mean that some recent events are not reflected in the data analysis for Chapters 4-6. Future research would benefit from including such events to assess their potential implications on the study's themes and conclusions.

3.7 Conclusion

To conclude, this chapter has outlined all facets of the research design and approach to ensure clarity over the approach taken. The research adopts an integrated approach, using Reflexive Thematic Analysis as the method of data analysis, identifying patterns within collected secondary data to shed

light on the research questions. Interpretation of the TA findings are informed by a New Materialist theoretical framework, allowing for an analysis which foregrounds the drone's materiality, capacities, and affordances in relation to the production of ambiguity and the potential role this technology way play within it. The overall analytical strategy is positioned with a constructionist orientation, aligning with new materialism, and encompassing the strengths of both inductive and deductive reasoning through the applied reflexive TA. This approach has been chosen due to its flexibility and acknowledgement of the researcher's theoretical stance and subjectivity as a central component of the analysis (Braun and Clarke 2021, 298). The advantages of this strategy lie in its capacity to maintain data-driven identification of patterns within the dataset, while allowing the flexibility for interpretation. This is important for this work, where theoretical concepts from new materialism inform aspects of the analytical process.

Overall, the approach aims to provide a richer landscape of analysis for gaining better understanding of the complex and emergent nature of the problem-space. It offers a unique way to interrogate the material affordances, capacities, and dynamics of drones, with the aim of exposing whether and how the drone contributes to the production of effects such as ambiguity in conflict and security contexts in addition to providing a mechanism for identifying the wider array of components or aspects enabling this capacity.

4. Mapping the Ambiguity of Drone Use

A central aim of this research is to understand the relationships, connections, and dynamics between drone technology and the phenomenon of ambiguity. Ambiguity is an observable emerging phenomenon around aspects of this technology's use, yet it is one not adequately explored or given due attention in existing literature (See Chapter 2). This chapter embarks on an exploration of this phenomenon as it pertains to the drone to identify the ways in which ambiguity can be observed in the context of this device and its use. Further, it seeks to ascertain an initial understanding of the factors, properties, or driving forces that may be enabling, affording, or facilitating the manifestation of ambiguity around drone use, to expose deeper insights into *how* this phenomenon occurs.

To embark on this exploration, a systematic approach was used to collect data relevant to the aims of the chapter and following the process outlined in section 3.3.1. Extant data collected includes official military doctrine, reports from International Organisations (IOs), articles from defence and security outlets, think tank reports and other research organisations, media reports, and defence and security solicitations. The dataset was subsequently analysed using Thematic Analysis following the approach of Braun and Clarke (2012) as outlined in section 3.4. This analysis identified three central themes associated with ambiguity in drone use: ambiguity surrounding operator identities; ambiguity pertaining to the context and purpose of drone use; and legal ambiguities. This chapter presents each theme in turn, drawing on examples from the dataset collected for this part of the study to elucidate them. Section 4.1 discusses challenges in identifying the operators of drones, highlighting how both the remote nature of drones, and their proliferation can contribute to challenges surrounding clear attribution, giving rise to multiple interpretations surrounding operator identity. Section 4.2 discusses the dual-use and adaptable nature of drones, shedding light on how these features can render determining the purpose and capability of drones – whether civilian or military – difficult, and open to multiple interpretations. Section 4.3 discusses legal ambiguities arising in relation to drone use, arising from transparency issues and lack of common frameworks around drone use. In section 4.4, two secondary or emergent themes are examined: deniability surrounding drone use, and the growing ubiquity of drones and its compounding impact on ambiguity. The analysis reveals an emergent cyclical relationship between the ubiquity of drones, the ambiguity that can surround them, and the deniability this ambiguity facilitates. Ultimately, this chapter charts a path to understanding the contemporary drone as an inherently ambiguous device whose essence is pluralistic; spanning a multitude of uses, operators, domains, and functions. These pluralities foster ambiguity, generating a web of potential interpretations around drones and their use in different ways and in different contexts. The chapter concludes with a reimagining of the drone as a *liminal vector*, emphasising its capacity to traverse not only physical domains, but also the thresholds, boundaries, and intersections of multiple uses, contexts, and interpretations.

4.1 Operator Ambiguity in Drone Use

> They come in the night: Drones — lots of them — flying in precise formations over the Colorado and Nebraska prairie. Whose are they? Unknown. Why are they there? Unclear.
> - (M. Smith 2020)

This opener for a New York Times piece about a series of unidentified drone sightings in the United States in 2020 gives a snapshot of the simplest form of ambiguity that can surround drone technology and its use. Ambiguity can arise in relation to who is operating a drone and why it is there. Lack of information about an operator's identity, coupled with competing possibilities due to a diverse user base introduce multiple interpretations that can make determining who is in control difficult.

Remote physical systems such as drones enable a crucial distance between the physical system and those operating it. Remote forms of action hold problematic implications such as distancing perpetrators from effects – whether physically, strategically, morally, or legally. Distancing can lead to difficulties in attribution and accountability, features that can be appealing to those utilising remote methods (Knowles and Watson 2018). A recurring theme that emerged during the analysis of data for this chapter resonates with these implications of distance and difficulties in attribution: ambiguity surrounding drone *operator identity* and ambiguity surrounding *origin of the device*. This section presents findings from a review of this material in relation to both military and consumer drone technology, drawing on examples to explore the various opacities surrounding who is operating a drone in a given situation. It highlights that it is not always evident who is operating a drone, where the device originated, or who the device is affiliated with. Importantly, it reveals it is not always possible to determine this information swiftly and accurately in order to implement an effective response. Each of these elements lend themselves to an overarching *anonymity* surrounding the use of drones in certain contexts, leading to the consideration of a principal enabler of this ambiguity: the cyber foundation of the drone and its characteristic anonymity.

4.1.1 Ambiguity of Operator in the Military Drone Context

It may be tempting to assume that there is no ambiguity surrounding the operator's identity when considering military grade drones and their use. When the U.S. conducts an airstrike using a drone, surely it is obvious it was the U.S. that carried it out? David Segalini touches on this in relation to drones and covert action:

> "…there is nothing covert about parking a hellfire in…the back seat of an SUV rolling through the desert. Other than Israel in its immediate environs, only one country on earth does

> this in the wider world. So by default, U.S. hand is all over every one of these strikes for all to see." (Segalini 2013).

Lacher echoes this when he alludes to the fact that in previous years, denying drone strikes would not have been plausible for the U.S due to its unique possession of strike capable drones at the time (Lacher 2020). Times have moved on. While it is not suggested that high level military drone strikes conducted by the U.S. have suddenly become anonymous, the picture internationally has become *less clear* due to multiple actors now wielding similar capabilities. Lacher makes an important point connected to this shift, highlighting that the U.S now has more reason to publicly acknowledge its drone strikes in Libya precisely to clarify any confusion in relation to other strikes carried out by different states using drones in that region (Lacher 2020). And this is the point about ambiguity. In today's drone saturated world, doubt *can* arise over who is responsible for events or incidents involving drones because multiple actors possess drones, often of similar design, and sometimes within the same theatre of operation (Gettinger 2019). Vast proliferation gives rise to a vast expansion of plausible narratives of ownership and operation surrounding the use of drones. The growing complexity of this identification issue as it pertains to military operations, specifically in the context of air control and active air and missile defence (Active AMD), is made clear in U.S. Counter Air Doctrine:

> "Airspace control in an active AMD environment is extremely difficult and becoming more complicated with the proliferation of unmanned aircraft systems. Rapid, reliable, and secure means of identification are critical to the survival of friendly aircraft and to facilitate an effective defense against enemy air and missile attacks." (U.S. Air Force 2019a, 30).

The possibility that friendly aircraft could be shot down accidently because of lapses in the ability to swiftly identify drones is a serious issue. Indeed, the increased risk of friendly fire incidents due to lack of identification in drones and other friendly airborne systems features as a key consideration for airspace control (U.S. Air Force 2019b, 53). The U.K.'s Future Force Concept outlines similar considerations in relation to control of the air in military operations, highlighting that the increasing ubiquity of drones "…will make sensing, identifying and engaging future threats increasingly complex." (U.K. Ministry of Defence 2017b, 42).

The challenge of identification is clearly linked to drone proliferation, which poses further difficulties for determining the origin of a drone. In 2018, difficulties arose in identifying whether two drones downed in Yemen were of Saudi Arabian origin or Emirati origin (Bassiri Tabrizi and Bronk 2018, 21). One of the drones was a CH-4, a Chinese made system like the U.S. Reaper and which both Saudi Arabia and United Arab Emirates possess. The widespread proliferation of similar drones to multiple actors plays a part in rendering identifying the operator and origin of a device more difficult.

The use of drones by violent non-state actors further highlights these challenges. The so-called "swarm" attacks using drones on Russian airbases in Syria during 2018 stand as a useful example (Reid 2018). The feature of "masked identity" has been aptly noted as a hallmark of such attacks, where – at the time of writing - still no perpetrators have been clearly identified (Balas 2019). Furthermore, we can observe challenges of operator and origin identification occurring outside the realms of conflict. A series of unidentified and coordinated drones massing in Colorado and Nebraska in 2020 caused confusion and hysteria. Following in-depth investigations, no clarity over these sightings has been found (Tait 2021). In reference to a Colorado citizen interviewed on the events, Smith writes, "Ms. George said she had heard wild speculation about who might be responsible for the flights – the government? a cartel? a gas company? – and feared they would never know the truth" (M. Smith 2020). These multiple interpretations and their plausibility are driven by the multiplicity of legitimate users of drone technology today. Drones have become easily accessible to numerous actors across multiple sectors and contexts. Pinpointing who is behind a drone operation in such an environment of plurality has, as this case highlights, become more difficult.

An incident in 2019 further highlights the challenge of anonymity. Unidentified drones made repeated incursions in the vicinity of U.S. Navy warships in the California Channel Islands, with ship communication logs revealing confusion and inabilities to identify the drones or their purpose (Kehoe and Cecotti 2021). Following official investigations, the identity and origin of the drones and their operators remain elusive (Crump 2021). Some have argued the origins are likely linked to nefarious state activity instigated by America's adversaries (Rogoway 2021). Such cases highlight the convergence of ambiguity that can occur when inabilities to identify the operator, the origin, or the capabilities of the platform itself cause doubt, speculation, and confusion. More crucially, these events uncomfortably reveal the lack of readiness that exists in response to the increasing use of drones around the globe.

The lack of identification on drone platforms can also contribute to operator ambiguity. Contrary to the Law of Armed Conflict and International Humanitarian Law which state that military aircraft must be identifiable through markings, some drones do not have such markings (Bassiri Tabrizi and Bronk 2018, 17). Indeed, Israel has reportedly used unmarked drones in Africa; an issue that makes identifying the origin of the drone more difficult. As a PAX report outlines, "Some Israeli unmarked drones fly circuitous routes to give the appearance that they are based in Egypt…both Israel and Egypt deny any Israeli involvement in the airstrikes." (Kurpershoek, Munoz Valdez, and Zwijnenburg 2021, 27). This example demonstrates that while lack of markings can make identification more difficult, so too can the drone's inherent remote nature. Drones do not necessarily have to be launched from the country to which they belong. The remote nature of drones opens up possibilities for manipulation – whether flying certain routes to give the impression of certain origins as in this

example, or through the digital manipulation of locational data to obfuscate identity and origin (Hartmann and Giles 2016).

Drone attacks on Saudi Arabian oil infrastructure in 2019 stand as a key example that illustrates both ambiguity of operator identity and origin of the device. This attack on the Abqaiq oil processing facility and Khurais oil field significantly reduced Saudi Arabia's oil and gas production and has been described as "an unprecedented attack on the world's energy supply" (BBC News 2019d). The attack was claimed by the Yemeni Houthi rebels, however, this was refuted by several states including the U.S, who directly blamed Iran (BBC News 2019b). Ambiguity abounds with this example precisely due to the plausibility that multiple regional actors could have carried out the attack. This ambiguity was reflected in the international response to events, with one UN envoy confirming it was "not entirely clear" who was behind the strike (BBC News 2019f). The event led some analysts to rightly highlight that "uncertainty is a core part of the drone's allure" (Rogers 2019b). However, such uncertainty is *created and enhanced* by ambiguity: the multiple interpretations that the device elicits. Further to demonstrating ambiguity of operator identity, this example illustrates the emerging complexity drone developments may be adding to being able to determine their origin. Indeed speculation arose as to whether dynamic manoeuvrability inherent to the design of the devices used had allowed them to approach the target from directions favourable to obscuring their true origins (Rogoway 2019).

4.1.2 Ambiguity of Operator in the Consumer Drone Context

The advent of consumer drone technology and its subsequent proliferation in both the civilian and military contexts adds a new layer of complexity to operator identification issues. A common factor cited regarding such difficulties in consumer drone systems is the sheer availability of them and the multiplicity of users this has produced. It has been noted that the widespread availability of consumer drones renders it possible that drone use "…could conceivably be from anyone," and that this in turn is a complicating factor for attribution (Sander 2016, 16–17).

Ambiguities relating to operator identity have been expressed in relation to data protection legislation. An EU report notes the difficulty people could have in identifying the operator of a drone or determining if it collecting personal data (European Union Committee 2015, 48). The unique features of the drone in comparison to other modes of data collection compound this issue:

> "With most CCTV cameras, even if it is not immediately obvious, you should fairly easily be able to track down the operator. With a camera phone, someone is holding it. If you see a RPAS buzzing around, who is controlling it? Where are they? Who is responsible?"(European Union Committee 2015, 64)

Here, the multiplicity of potential users coupled with the remote and mobile nature of the drone complicates attribution by introducing multiple interpretations over responsibility. The ramifications of such ambiguity are highlighted in an impact assessment of drones by the Department of Transport which notes: "[f]ollowing an accident or a breach of the rules it is difficult to identify the drone owner and the police lack the sufficient power to pursue offenders." (Department for Transport 2017).

Anonymity afforded by drones and the ambiguity this can instil could be leveraged in ways that cause chaos. We can already observe glimpses of this, such as the thirty-six hours of chaos caused by drones at Gatwick Airport in December 2018. Reported sightings of drones over the airport's runways brought the airport to a standstill, with thousands of flights being cancelled and hundreds of thousands of passengers disrupted (Haider 2020, 48). At the time of writing, still no perpetrator has been apprehended for the events that took place during this incident. Drone experts pointed out how this event showcased the "impunity" that drone technology bestows upon its operators (Holland Michel 2019, 9). Such impunity raises concerns about the potential appeal of drones for the conduct of more devastating attacks. This is echoed in a report regarding security against terrorism, where the risk of drones being used for such purposes is considered high (Vasilis and Martin 2020, 84). Among the appealing features attributed to this level of risk are the availability of such systems and the anonymity they afford.

4.1.3 Anonymity: A Trait from Cyberspace

This section has demonstrated that ambiguity can arise in relation to the operator of a drone and its origin. While it is not contended that this is *always* the case, these examples actively illustrate that these pieces of information may not always be clear or readily apparent. A certain level of anonymity can be observed in relation to drones, but how does such anonymity occur and what makes it possible? While beyond the scope of the present chapter to explore this in depth, the anonymity in the examples explored so far has been tightly coupled with the drone's remote operation. The drone operates through cyberspace – a domain described by some as inherently ambiguous (Libicki 2011, 4). The problem of attribution in cyberspace is widely acknowledged, offering actors a certain level of anonymity (Reich et al. 2010, 35). The drone – as a cyber-physical system reliant on cyberspace – appears to have inherited the inherent ambiguity of the cyber domain. Both the cyber domain and drones enable users to place a crucial distance between themselves and the effects they can be used to achieve. The cyber-physicality of the drone can be considered an intrinsic property that enables anonymity to occur in relation to operator and origin; suggesting it is a key driver in relation to the ambiguity of the drone. We can thus begin to observe the drone's cyber-physicality enabling or facilitating ambiguity through the dislocation it allows contributing to, and exacerbating, attributional issues.

4.2 Purpose Undefined: The Ambiguity of Drone Operations

> Drones are here to stay – in backyards and battlefields, in the hands of militants and militaries, conducting both surveillance and air strikes (Barsade and Horowitz 2017).

Ambiguity in relation to the *purpose* of drone use emerged as a second major theme during data analysis. The findings explored in this section demonstrate ambiguity arising from difficulties ascertaining the purpose and capabilities attached to a drone's presence. Two key factors were identified in contributing to ambiguity of purpose: a) the *dual-use* nature of drone technology; and b) the *adaptability* of drone technology. Moreover, it was found that ambiguity of purpose is exacerbated by inabilities to determine the operator as previously discussed in section 4.1.

4.2.1 The Dual-use Dilemma

Drone technology is *dual-use*. Dual-use technologies are those that can be used for both military and civilian purposes (Molas-Gallart 1997, 370). The dual-use nature of the drone has given rise to significant overlaps in the adoption of drones across the civilian and military contexts. The growing number of consumer drones in military inventories is one example (Gettinger 2019). Such overlaps increase the number of plausible possibilities as to who is operating a drone and also increases the number of plausible possibilities as to the *purpose* of a drone flight. This arises due to the *plurality of legitimate contexts* that drone technology can be used in. The dual-use nature of the drone goes beyond their application in both military and civilian roles to the very dual-use components that go into making them (Schulzke 2019, 498). The depth of the drone's dual-use nature emerges as a key driver of ambiguity related to the purpose of drone use, blurring distinctions between drone use across contexts (Dunn 2013, 1238).

This is an issue that has been readily acknowledged in the context of arms control. Drones developed purely for civilian applications can be harnessed by militaries and potentially weaponised (Alwardt 2020, 416). The regulation and tracking of such applications of civilian dual-use technology is challenging. Alwardt uses the term "military indeterminacy" to refer to inabilities to verify the military nature of drones, particularly those lacking distinct military attributes. He contends verification may only be possible after the resulting effects of the system become apparent through its use (Alwardt 2020, 416–17). Such indeterminacy also poses challenges in the context of both peacetime operations and conflict. The expansion of civilian drone use presents opportunities for misinterpretation in peacetime, particularly where the capability to identify non-threatening drones is lacking (Alwardt 2020, 262). The increasing adoption of military and consumer drones by both state and non-state actors compounds these challenges. This complexity is illustrated in the use of

consumer drones by Daesh in Iraq and Syria, where multiple parties to the conflict employed consumer drones (Waters 2017). The plurality of similar devices in use gave rise to deceptive tactics. Specifically, Daesh is reported to have intentionally waited for the Syrian Democratic Forces (SDF) to deploy their own surveillance drones before deploying their own weaponised devices; making it difficult for SDF troops to distinguish between them (Gibbons-Neff 2017). The ability for troops to visually differentiate between hostile and friendly systems is not always easy and the increasing employment of consumer drones by both state and non-state actors has compounded this issue (Lamport and Scotto 2016, 2).

Developments in civilian drone technology are poised to further exacerbate challenges in distinguishing between civilian and military systems. Where large payload capacities of drones previously hinted at their military nature, consumer drones are increasingly designed with large payload capacities to facilitate the many roles they can undertake (Lamport and Scotto 2016, 416). The blurring of this line will only become blurrier as drone technology advances (Ewers et al. 2017). Ongoing developments in swarming drones with more autonomy, and smaller drone systems are considered to pose significant challenges to such distinctions, especially in the context of arms export control (Dorsey and Bonacquisti 2017, 31). The blurring is considered a direct consequence of the dual-use nature of the technologies utilised in developing such drones and their "novel assemblage options that facilitate an easy transformation of a civilian drone into an armed drone." (Dorsey and Bonacquisti 2017, 31–32). Furthermore, distinctions between civilian and military drones stand to become blurrier still as collaboration between civilian drone industry and militaries intensifies (Bassiri Tabrizi and Bronk 2018, 18).

4.2.2 Adaptability

The adaptability of the drone also plays a role in ambiguity surrounding a drone's purpose. Drones are highly versatile. The vast array of uses for drones presents a constellation of possibilities as to what a drone might be being used for in a given situation. While it would be remiss to overlook things such as context, circumstance, and location – which may be used to narrow down such a list of possibilities, it remains that due to their versatility and remote operation, there exists a plurality of plausible roles that a drone may be carrying out in any one given context or location. The previous discussion about the dual-use nature of the drone highlighted that making clear distinctions between civilian and military drone use can be difficult. This section highlights that even in instances where a drone system *can* be clearly identified as military or civilian, ambiguity may still arise in relation to what *kind* of mission that system is conducting.

In the military context, there are multiple possibilities that exist in relation to what role a drone may be employed in. Among the multi-role capabilities of military drones are intelligence, surveillance and reconnaissance (ISR), target identification, electronic warfare, cyber capabilities, communications relay, and kinetic strike capabilities (Springer 2013). Against the backdrop of increasing drone use, inabilities to swiftly determine if a drone is armed could potentially cause misinterpretation or miscalculation (Sander 2016, 19). We can observe examples where overly forceful responses have been implemented to what were later confirmed to be unarmed drones. For example, following an incident in which a Syrian drone entered Israeli airspace, two helicopters and four fighter jets were scrambled by the IDF to identify and neutralise the threat, later found to be unarmed (Woodhams 2018, 12). Lack of clarity surrounding how actors may respond to a drone in their territory has been noted as risking misperception (Ewers et al. 2017, 16). Ambiguity of purpose coupled with ambiguity of response thresholds could present significant challenges going forward. Inabilities to distinguish the purpose of a drone's presence hold significant implications, one example being in relation to the laws of war. In discussing the use of defensive force, Michael Glennon considers how conditions of uncertainty can expose grey areas in international law (Glennon 2018). Using the example of a drone incursion into a state's territory, he asks: "[h]ow is the latter state to know whether the drone's controller is 'preparing the battlefield' for an armed attack or is merely conducting surveillance – or whether the drone itself is armed?" Glennon raises a good point that underscores the significance of ambiguity in relation to drones. Where there is ambiguity, there is manoeuvrability. This manoeuvrability occurs in relation to the interpretation of the narrative underpinning drone use in a particular circumstance and the ability for this narrative to be manipulated to serve specific agendas.

The growing need for flexibility in military systems and operations is an important driver of adaptability in weapon systems, including drones. An example of this rests in the capacity for some drones to carry out multiple roles in a single operation, including being re-tasked post-launch. This "mission flexibility" has been noted as a key part of their appeal (Joint Air Power Competence Centre 2010, 2). This may be operationally useful, yet it demonstrates a key ambiguity: lack of clarity surrounding what role or purpose a drone has at any given time during its flight. It raises questions about the intentional leveraging of ambiguity and even the design of ambiguity into such systems. Going forward, ambiguity of purpose may be heightened as militaries continue to seek increasingly flexible and ad-hoc capabilities. The U.K. MoD's many drones make light work competition highlights this aim. The competition solicitation for the project noted that a key aim is to develop concepts that allow assemblages of various distinct platforms with various distinct capabilities to be put together at the last minute before a mission begins (U.K. Ministry of Defence 2016). Such flexibility in platform configuration coupled with the potential for a drone's assigned role to be changed at any point post-launch introduces a high level of ambiguity; a potentially unknowable configuration with ambiguous capabilities and ambiguous purpose. Moreover, the advent of so called

"applique kits" – software enabling the conversion of existing vehicles or aircraft into uninhabited systems – further demonstrates how the growing adaptability of drone technology may frustrate existing ambiguities in relation to ascertaining the purpose behind a system's use (Ewers et al. 2017, 15). A significant implication of the drone's adaptability is that it can add further complexity to ambiguities already arising from the drone's dual-use nature. Alwardt contends that "[a] purely external, unambiguous distinction between civilian and military unmanned systems is…considerably exacerbated by their system complexity and dual-use character." He highlights that it may be possible for weapon payloads and software to be removed or replaced in a way that obfuscates the intended purpose of a drone, with such adaptations allowing for military drones to be disguised as civilian ones (Alwardt 2020, 417).

Challenges associated with being unable to determine the purpose of a drone's presence extend beyond the military use of drones. This is evident when looking to a study on data ethics and privacy in the use of civil drones which highlights the trouble citizen will have relating to determining what payload a drone may be carrying, what it might be doing or collecting, and indeed who might be operating it (European Commission 2014, 32). The capacity for drones to be equipped with numerous and divergent payloads gives rise to multiple plausible possibilities and interpretations as to what a drone is being used for. The same study goes on to highlight that "…it is difficult, if not impossible, even for individuals noticing such devices, to know who is observing them, for what purposes and how to exercise their rights."(European Commission 2014, 44).

This section demonstrates how the dual-use and adaptable nature of the drone can give rise to ambiguity surrounding the context and purpose of its use. These properties, and the plurality of legitimate contexts of operation they allow for, heightens the ambiguity surrounding drone technology by increasing the number plausible narratives as to what context the device is being operating in (civilian or military) and in what capacity the drone is being employed (surveillance, legitimate, illegitimate usage).

4.3 Legal Ambiguity

Legal ambiguities constitute the final theme identified when exploring data for this chapter. Many legal debates around the use of drones have featured prominently in the drone discourse for the past two decades (Boyle 2018; Rosén 2014; Završnik 2015; Lewis 2011; T. Gregory 2015; Sterio 2012). It is not the aim of this section to replay this narrative, rather, to highlight areas of ambiguity that exist therein, exploring their interactions with the phenomena of ambiguity. This includes issues like the lack of transparency in operations, facilitated by the distance between operator and device. Moreover

it includes the lack of common regulatory frameworks and norms of use around drones, underscored by its rapid adoption and evolving nature of its use. Ultimately, these legal ambiguities can be traced in relation to ambiguities driven by the technology's inherent cyber-physicality and adaptability.

4.3.1 Lack of Transparency and Accountability

The transparency and accountability issues that drones can facilitate are a crucial challenge. This has been widely acknowledged in scholarly literature spanning many disciplines, including international relations, law, and human geography (Warrior 2015; Boyle 2018). Some scholars have pushed for the development of a global accountability regime for regulating drones (Buchanan and Keohane 2015). Discussion of transparency and accountability challenges related to the use of drones include issues such as opacities arising from the lack of disclosure of civilian casualties, secrecy surrounding targeted killing operations and the lack of oversight in relation to use of private contractors for drone strikes (Knowles and Watson 2018; D. Brunstetter and Braun 2011b; Emmerson 2016; Kerrigan 2019). A fundamental element that underpins both transparency and accountability issues is the distance that drone technology places between operator, device, and effects.

Where lack of transparency becomes more interesting for the present exploration of ambiguity and the drone is in the *manoeuvrability* it can enable. The manoeuvrability that an intentional lack of transparency can afford an actor in relation to the use of drones can be seen in the example of the U.S. being purposefully vague about the drone strikes it conducts – precisely to maintain its freedom of action (Ewers et al. 2017, 5). Specifically, however, it is manoeuvrability in relation to the *narrative* of drone use and the differing interpretations this flexibility can incite that is of interest here. Where there exists a lack of clarity about drone operations, there exists the possibility of multiple interpretations as to what is occurring, where it is occurring, why it is occurring, and by whom it is being carried out. The expansion of the deployment of drones in Africa stands as a good example that can help illustrate this. According to one report, " both the US and Niger have remained vague about why, when, where and how drones would be deployed exactly," precisely in order to avoid controversy or backlash over this foreign intervention (Kurpershoek, Munoz Valdez, and Zwijnenburg 2021, 17). Deliberately withholding information creates ambiguity around a situation. This ambiguity can be leveraged as a way to control or limit the narrative surrounding drone operations to one's strategic advantage. In the context of the example just given, that strategic advantage is the avoidance of political or local backlash.

The distance placed between drone and operator also raises legal ambiguities in relation to where responsibility lies for an operation. Lack of transparency can thus feed directly into accountability issues. An example can be seen in the purposeful opacity of command and control (C2) structures

surrounding the use of drones. For example, the UAE has not disclosed its C2 procedures in relation to the use of armed drones which may be intentional to evade accountability (Bassiri Tabrizi and Bronk 2018, 31). Attributional concerns have also been identified in relation to the outsourcing of drone operations to private companies. Specifically, legal concerns over how this can muddy the water in relation to identifying the who is responsible and thus giving rise to accountability challenges (International Institute for Peace 2014, 2).

We can trace these issues of both transparency and accountability, in part, back to the cyber-physical nature of drone technology. In the case of transparency, the fundamental cyber-physicality of the drone enables a disconnection or distance between operator and operation; giving rise to opacity and driving ambiguity in relation to what is occurring, where it is occurring and by whom. In the case of accountability, the fundamental cyber-physicality of the drone enables a disconnection between operator and system; giving rise to opacity of the operator as previously discussed in section 5.1.

4.3.2 Lack of Common Framework for the Use of Drones

A second theme pertaining to legal ambiguity involves lack of common frameworks for the use of drones. Indeed, it has previously been acknowledged that drone adoption outpaces many states' ability to establish frameworks to regulate the use of drones and their procurement (International Institute for Peace 2014, 2; Vacca and Onishi 2017). The advent of the consumer drone has seen this trend continue, with some highlighting the urgency of putting legal frameworks in place to regulate them (Nugraha, Jeyakodi, and Mahem 2016; Vijeev, Ganapathy, and Bhattacharyya 2019; S. J. Fox 2017). This lack of a common framework amid the backdrop of the rapid expansion of drone adoption globally presents a significant challenge, one that also gives rise to ambiguity. While in 2020 the first EU-wide framework for the regulation of drones came into effect – no overarching framework for the use of commercial drones exists internationally (De Schrijver 2019, 340–41).

The expansive use of drone technology by multiple actors on the world stage is a relatively recent occurrence. Accordingly, the 'rules of the road' for drone use are still being established as actors experiment with this technology. Indeed, as one expert puts it "…because drones are new, actors can define the message of drone use and respond to others' uses at their own discretion."(Sander 2016, 17). The power to 'define the message' is an exceptionally important point which relates back to previous discussion of transparency and ambiguity as a mechanism of control. Precisely due to the 'newness' of the drone's accessibility and growing ubiquity, there is vast manoeuvrability in relation to how one interprets or responds to this technology. As Sander contends, this has been exacerbated by the lack of a common framework for the use of drones, or indeed, established legal norms for responding to them (Sander 2016, 17).

An example demonstrating the ambiguity surrounding norms of use and response is the seizure of a U.S. UUV by the Chinese Navy in 2016 (BBC News 2016). Although this example relates to an underwater drone and not an aerial drone system, the example is useful to illustrate the kinds of knee-jerk defensive response actors may take in response to a system or vehicle where there exists a lack of common understanding or framework for use. In an assessment of this incident, it has been noted that lack of legal clarity surrounding the use of such systems is a likely reason why the Chinese Navy reacted the way it did (DCDC 2018, 42). As some aptly note:

> "…lack of explicit international policies for drone use, have resulted in norms of behaviour that prize strategic ambiguity, allowing states to deploy or respond to uninhabited aircraft in whatever manner is expedient in the moment." (Ewers et al. 2017, 15)

These issues pertain directly to inabilities to ascertain the purpose or intent behind drone use. As previously discussed, multiple possibilities exist for the purpose of use behind a drone in any given situation. This reality is echoed by Sander who contends "there is no specific intent associated with the use of uninhabited aircraft…" (Sander 2016, 17)

4.4 Ubiquity: The Ambiguity Amplifier

The proliferation of aerial drones throughout the military and civilian spheres has led to their increasing ubiquity (Sayler 2015, 10). As of 2019, 95 states hold an active military drone inventory, with 21,000 drones confirmed in service around the world (Gettinger 2019). Recognition of the drone's utility is echoed by its rapid pace of proliferation (Fuhrmann and Horowitz 2017, 415). Today, aerial drones are no longer solely the realm of technologically sophisticated state militaries as they once were. Small states who previously may not have been able to attain an aerial capability have been able to do so through drone technology (Rogers 2021b). As consumer drones have become more accessible, the democratisation of the drone has expanded further (Hurst 2019, 20). This has provided a diverse array of actors with "easy access to the air", presenting many challenges in the context of defence and security (Hastings-Dunn and Wyatt 2018, 4; Abbott, Clarke, and Hickie 2016; Rogers 2019b; Chávez and Swed 2021; Cronin 2019).

While cognizant of the various economic, political, and geostrategic drivers of military drone proliferation, a less considered factor is the duplication and cloning of drone designs through mass production, technology transfer, theft of intellectual property (IP), and reverse engineering. We continue to see efforts by state actors to match their drone designs to other competing platforms. This is the case with China's Wing Loong 2 and other variants, which in appearance, are exceptionally similar to the U.S. MQ-9 Reaper which came before it (Risen 2017). The capture of a U.S. RQ-170 Sentinel drone by Iran in 2011 paved the way for multiple claims by Iran that it successfully reverse-engineered the drone to inform the production of its own copies (BBC News 2012). Iran's Shahed 171 and Saeqeh drone platforms are largely reported to be the result of those reverse-engineering efforts

(Cenciotti 2014a; Opall-Rome 2018). Other examples can be found in Iran's "exact pirate copy" of the U.S. Scan Eagle drone, manifesting in Iran's Yasir drone, unveiled a year after the capture of the U.S. drone (Hambling 2020a). Duplication of drone designs contributes to many similar drone systems emerging in the international arena. While many copies or 'clones' lack the power and sophistication of the platforms they mimic, this growing ubiquity of visually similar systems presents challenges around identification. This becomes evident when looking to conflicts in specific regions where multiple actors leverage similar, or the same, drones (Gettinger 2016). While the strategic ramifications of this are yet to be fully felt, we are seeing glimpses of the emerging complexity of this duplicity as previously discussed in section 4.4.1.

Mass production and sheer accessibility of consumer drones also contributes to the plethora of similar drones in use by various actors. From Non-Governmental Organisations (NGOs), activists, and emergency services, to state and violent non-state actors - similar drones may be in use by multiple parties. Furthermore, consumer drones are commodities; as such, this increases the knowledge base for cloning, adaptation and modification. As Jackman points out, the DIY drone community has access to an abundance of instructional resources online (Jackman 2019, 10). This is reflected in the abundance of ad-hoc and home-made drones being made in various situations, including conflicts (Wendle 2018). As drones become more ubiquitous and when systems look the same or resemble those of another actor, attribution, capability determination, and understanding the purpose of the drone can become more complex. While post-incident analysis may reveal more information, immediate determinations can remain a challenge. While it would be remiss to overlook the importance of motivation and intent in relation to attribution, at the most basic level, as the number of actors with access to drones – or the capability to build them – rises, the number of possibilities as to who may be operating it, what it can do, and why it is in a particular scenario rises alongside it. This multiplicity of interpretations generates ambiguity, which in turn holds potential to decrease one's level of confidence in immediate, accurate attribution. We can thus start to understand the extrinsic phenomenon of ubiquity as a central amplifier of the ambiguities already arising in relation to the drone's origin, operator identity, and purpose.

4.4.1 The Ubiquity-Deniability Cycle

The drone's ubiquity acts as a force amplifier for ambiguity. Drone ubiquity increases the number of plausible interpretations as to the drone's operator, origins, capability and purpose. Throughout the analysis of data for this chapter, a pattern became clear through the recurring colocation of three codes: ambiguity, ubiquity, and deniability. This pattern is important as it elucidates a key significance related to the multiplicity of narratives the drone can elicit – the *deniability* it facilitates. One example of such a collocation is as follows:

> "This 'deniability' has important political, legal, and strategic implications. Holding actors to account, or retaliating against belligerents, is difficult in this deniable, multi-user context, where similar, if not identical systems, are deployed by myriad disparate actors" (Rogers 2021a, 482).

Deniability is discussed here in relation to the ubiquity of drone users and difficulties in distinguishing similar drone systems. Multiplicity of actors and multiplicity of systems gives rise to multiple interpretations – and thus ambiguity related to who to hold to account. Many such collocated paragraphs came to light which held issues of deniability, multiple users, similar systems, and ambiguities resulting from these complex interactions in close proximity. As demonstrated throughout the preceding sections, multiple ambiguities can arise in relation to drones and their use. Namely, ambiguity of operator identity, ambiguity of purpose, and ambiguity arising from a lack of regulation, norms and standards in relation to their use. Each appear to contribute to the deniability of drone use through the multiple interpretations they foster. Each also appear to be exacerbated by the extrinsic phenomenon of ubiquity.

Denial and speculation over attribution following drone incidents can be observed in various contexts. From territorial incursions, drone shoot downs and crashes (UAS Vision 2015; Hubbard 2019; Chabin 2013; Al Jazeera 2019; A. Khan 2020; BBC News 2018b), to flyovers of CNI (Shackle 2020a; BBC News 2014; Hambling 2020b), and kinetic attacks (BBC News 2019c; Sly 2018). The growing ubiquity of drones can be understood as a catalyst that compounds existing issues relating to anonymity as well as issues relating to ambiguity of purpose. The multiplicity of users that are associated with the use of drones amplifies the possibilities as to the number of plausible operators at any given time or context. In turn, this also amplifies the number of reasons that a drone may be in use. The notion of ubiquity as an external catalyst of ambiguity is strengthened when looking back to collocated examples from the dataset. As Sander contends, increasing drone use amid *existing* difficulties in attribution is likely to exacerbate such challenges, increasing the chances of misperception regarding the purpose of drone use, possibly leading to miscalculations (Sander 2016, 19). Callamard and Rogers also place ubiquity and operator anonymity in proximity when discussing the increasing adoption of drones for targeted assassinations: "The proliferation and evolution of drone technology puts such killings within the reach of multiple state and non-state actors, who may kill anonymously and with impunity." (Rogers and Callamard 2020). Anonymity here, is again exacerbated by the multiplicity of actors with increasing access to such means of killing.

Identification challenges magnified by a plurality of actors and systems create the ideal conditions for plausible deniability to flourish. Indeed, Rogers hypothesises a future in which distinguishing between state and non-state actor drone strikes will become more difficult due to states purposely creating an

"air of deniability" by supplying non-state actors with drone systems identical to their own (Rogers 2021a, 499). We are already seeing this play out. Following the 2019 drone attack on Saudi Arabian oil infrastructure (discussed in section 4.1.1), plausible deniability arose due to Iran's affiliated proxies possessing similar drone systems (Rogers 2019b; Rogoway 2019). This is further highlighted in examples where multiple parties to a conflict operate similar drone systems. In relation to the conflict in Libya, Lacher points out that in situations where a drone has been shot down, both parties tend to claim that downed aircraft belonged to their opposition (Lacher 2020). Such contentions gain plausibility through the similarity and ubiquity of drone systems in use. It is considered that challenges associated with ongoing drone proliferation and the similarity of systems among a multiplicity of actors are likely to increase going forward (Rogers 2021a). This presents a foreboding glimpse of what may be over the horizon, as the purposeful leveraging of ambiguity surrounding drones becomes easier due to its increasing ubiquity. These insights highlight the connection between ambiguity, the extrinsic property of ubiquity, and deniability in drone use. Figure 6 presents a proposed relational cycle linking these elements. Ubiquity is understood as having a catalytic effect on ambiguities already arising in relation to the drone. Specifically, ubiquity *exacerbates* ambiguity surrounding the operator, origin, and purpose of drone use by intensifying the number of possible narratives behind each of these factors. This fosters deniability by creating additional plausible interpretations as to the possible operator, origin, and purpose. Deniability, in turn, further exacerbates ambiguity. Thus, a critical feedback loop is created in which ambiguity gives rise to deniability, deniability maintains that ambiguity, which in turn preserves the condition of deniability. This feedback loop is considered here as a deniability mechanism. The recognition of the utility of this deniability mechanism may then feed back into the proliferation and ubiquitous adoption of drone systems.

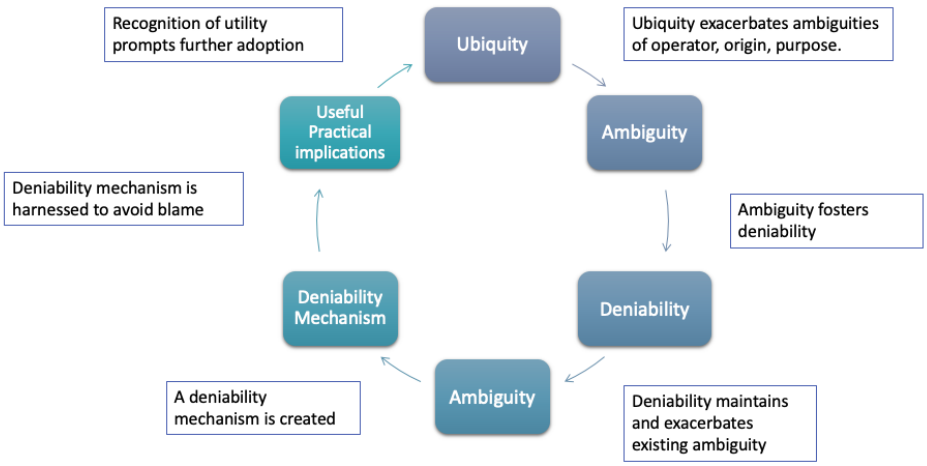

Figure 6. The Catalytic Effect of Ubiquity on Ambiguity.

4.5 Physical Manifestations of Ambiguity: The Drone, Deniability, and Subthreshold Activity

Through exploring ambiguities relating to the drone, this chapter maps the most prominent ways we can observe ambiguity around the drone and its use. It identified four overarching areas where we can see ambiguity pertaining to the drone arise: anonymity surrounding operator identity and origin of the device; the adaptability of drones giving rise to multiple purposes and functions; legal ambiguities including transparency and accountability issues; and the ubiquity of the drone allowing for its use by multiple actors. These aspects were found to contribute to a multifaceted ambiguity around the drone and its use. It further explored the emergent theme of deniability in relation to the drone's growing ubiquity and its amplification of ambiguity surrounding drone use.

This concluding section presents an overview of the key findings and brings them into dialogue with existing work related to ambiguity and drones. It underscores the relevance of closer consideration of the underlying components and properties enabling and facilitating certain drone practices – something thus far insufficiently attended to in the literature. Ultimately, this section argues for an understanding of the drone as a liminal system, which takes inspiration from Kilcullen's notion of liminal warfare (Kilcullen 2020). A liminal conceptualisation of the drone foregrounds its capacity to blur and traverse conventional boundaries and categorisations while simultaneously conjuring a multiplicity of plausible interpretations pertaining to functionality, purpose, operator, and origin.

4.5.1 Plausible Multiplicities and the Plurality Paradox

Findings from this chapter see the drone emerge as an inherently ambiguous device. This is a technology with a vast scope of applications, across a diversity of domains and contexts. It is a technology whose versatility and multiplicity cater to an extensive pool of users, and for a diverse range of uses. Further, this is a technology whose growing ubiquity magnifies these pluralistic qualities. This web of multiplicities surrounding the drone give rise to a multiplicity of possible interpretations and thus multiple plausible narratives pertaining to it. Whether multiple interpretations as to who might be operating the drone, or its origins, to multiple interpretations as to the drone's context and purpose of use. This chapter produced the following mapping of the drone's plurality and its association to ambiguity as shown in Table 2.

Table 2. The Intersection of Drone Plurality and Ambiguity

Category	**Description**	**Resulting Ambiguity**
Plurality of Context	The drone's dual-use nature gives rise to a plurality of legitimate contexts of operation spanning a diverse range of civilian and military contexts.	This plurality generates ambiguity around distinguishing clear context of use.
Plurality of Function	The drone's multi-role nature gives rise to a plurality of capabilities and roles, from surveillance, and data capturing, to weaponisation.	This plurality generates ambiguity surrounding purpose and capability.
Plurality of Operators	The drone has a vast spectrum of potential users, from state actors, and non-state actors, to civilian, commercial, and hobbyists.	This diversity produces ambiguity pertaining to operator identity.
Plurality of Platforms	Driven by proliferation, accessibility, and the similarity of drone systems, a wider array of drone platforms are in use across a diverse range of actors.	This plurality further compounds ambiguity surrounding context of use, purpose and capability, and operator identity.

While drone technology is attractive precisely for its multiplicity of applications, this inherent flexibility introduces a plurality paradox. The ability to accurately or swiftly discern a *clear and singular narrative* around drone use may be diminished by its multifaceted plurality. Each context of drone use carries with it a set of diverse possible narratives pertaining to its presence. This presents new dilemmas that we are only beginning to see a flicker of in the international arena. As this chapter has highlighted, we can observe instances where this multiplicity of narratives can be seen playing a role in the generation of confusion. The drone's plurality generates ambiguity through eliciting multiple interpretations regarding operators, origins, purposes and capabilities. Drones are emerging as tools that offer new avenues for nefarious actors to exploit ambiguity and complicate situations or response strategies. It is important, consequently, to take the drone's inherent plurality into account when conceptualising this technology.

4.5.2 The Drone as a Liminal System

To bridge this conceptual lapse, a reimagining of the drone that encapsulates its capacity to generate multiple interpretations is required. It is within this context that we can think of the drone as a *liminal system*. The notion of liminality draws inspiration from Kilcullen's Liminal Warfare theory, which seeks to emphasise the *manipulation of thresholds* – and the ambiguity found therein – central to many aspects of contemporary Russian operations (Kilcullen 2020, 150). It is the focus on *thresholds* that is of central interest here to our adoption of the liminal terminology.

Drone technology exemplifies the notion of liminality. As a conceptual frame, liminality captures the *plurality of narratives* surrounding the drone that the work throughout this chapter has exposed. To be

liminal is to be positioned "…on a boundary or threshold, esp. by being transitional or intermediate between two states, situations…" (Oxford English Dictionary 2023c). The drone's cyber foundation – imparting to it a certain anonymity – holds the capacity to blur distinctions between operator identities. Its multi-role and dual-use nature hold the capacity to blur the boundaries between civilian and military use, offensive and defensive use, legitimate and illegitimate use. Further to this, the drone can also be considered liminal in relation to its existence at the thresholds of laws and legal frameworks. An understanding of the drone as a liminal system emphasises this technology's multidimensional capacity to blur boundaries and distinctions, and to move ambiguously between them – whether in reality or in perception – the drone exists at the thresholds of different uses, users, functions, and contexts.

This conceptualisation is important as it allows us to begin exposing and unpacking the constituent parts that 'make' the device useful in certain contexts. As outlined in Chapter 2, ambiguity has been acknowledged in relation to drone technology, yet not meaningfully unpacked (Mumford 2020; Carlucci and Mumford 2023; Hwang 2021). Hwang presents an assessment of the ways in which drones can be useful within ambiguous strategies. He discusses their use in salami slicing tactics; in allowing actors to feign innocence, and their use by proxy forces (Hwang 2021, 338–39). Yet, beyond noting the low cost of drones and their lack of a pilot, the author makes no attempt to understand at a deeper level what makes the drone apt for such tactics. There is more at play here, requiring more than a general nod to the drone's low cost and 'unmanned' nature. Indeed, these works fall short of offering a detailed exploration or analysis of *how* certain conditions (like ambiguity) are created, produced, or enabled through the tools they explore. Rather, their focus is on the *tactics used by actors* wielding drones and how this may subsequently contribute to ambiguous strategies. While certainly an important aspect of study, it offers an incomplete reading of the dynamics at play. The human-centric nature of such analyses prohibits the level of critical enquiry necessary to elucidate the broader set of 'things', properties, and interactions that allow or facilitate the tools' use in the tactics explored. Yet, it is only by reaching this deeper level of analysis that we can fully comprehend what is occurring, how it is occurring, and why it is effective and challenging. It is here that a conceptual reimagining of the drone as a liminal system is particularly important for deepening our understanding of its efficacy in ambiguous strategies. By focusing on the 'how' and the 'why' questions around drone ambiguity, we can begin to build a deeper analytical framework that goes beyond just the operational tactics, exposing the intrinsic properties of the technology that lend themselves to both the production and maintenance of ambiguity.

Cognitive Liminality

The potential for ambiguity to produce indecision is recognised (Mumford 2020; Carlucci and Mumford 2023). Indeed, Carlucci and Mumford discuss the notion of the cognitive impasse in relation to ambiguity in hybrid warfare, outlining the capacity for certain tools and tactics to purposefully bring an adversary's decision-making to a halt (Carlucci and Mumford 2023, 199). It is in this context that they briefly mention drones among a list of tools and techniques with the capacity to produce such an impasse. However, akin to Hwang, the authors stop short of providing an understanding of *how* this happens, treating both the ambiguity and resulting impasse as a simple by-product of a tool's utilisation. This is an oversimplification that fails to notice and pay due attention to the intrinsic properties of the drone with the capacity to contribute to and actively induce the condition of ambiguity. An understanding of drones as liminal systems can help elucidate a more nuanced understanding of the *processes* by which the drone – and its intrinsic plurality – contribute to the production of such a cognitive impasse.

When perceptions of drone use become *untethered to a singular narrative*, the resulting ambiguity creates opportunities for plausible deniability. Plausibly deniable actions are understood here as actions of influence undertaken in such a manner as to evade the burden of proof (Walton 1996; Cormac and Aldrich 2018). This can be leveraged by actors in multiple ways for strategic advantage: to create confusion; slow decision-making or responses; avoid culpability; or obscure true intentions. Plausible deniability has an intrinsic link with ambiguity, it both fosters ambiguity and is in a sense, nurtured by it:

> "*Plausible deniability is preserved by ambiguity*, and other deceptive or confusing techniques that enable an arguer to keep the back door open, should one's argument be directly confronted or challenged." [emphasis added] (Walton 1996, 50).

The drone's ambiguous nature – in its capacity to conjure multiple interpretations and competing narratives around its use or presence – presents multiple opportunities for plausible deniability to be preserved, making them well suited to ambiguous strategies or contexts. Indeed, it is within the broader spectrum of subthreshold contexts that the drone's ambiguity can truly flourish. It could be argued that it is the ambiguous context of the grey zones within which they are being used that thus generates the ambiguity. However, akin to the grey zone itself, it is not that black and white. This work advocates for an understanding of the drone as an active participant in the ambiguity that can surround its use. This understanding follows Bennetts vital materialism, which emphasises the capacity for objects to both influence and be influenced by their environments (Bennett 2010). Indeed, this work demonstrates that the drone clearly houses a distinct set of inherent properties making it apt for use in such contexts – properties that enable and facilitate the production of multiple narratives. This plurality of narratives around drone use, in challenging abilities to swiftly determine purpose,

context of use, operator, or capability, can thus produce what we will term here a 'cognitive liminality'. Cognitive liminality refers to the way in which clarity of determining one or more of these factors is challenged due to the multiplicity of plausible narratives surrounding the drone. In essence, cognition is seized at the thresholds of these various possibilities. The drone's ambiguous nature can thus be seen as having an active *influence* on decision-making and cognition. This supports the recognition of the active role that the drone's non-human properties – such as its adaptability and cyber foundation – can play in shaping outcomes or perceptions.

The ample scope for manipulation of ambiguity surrounding drones, particularly in relation to attribution, illustrates that these devices are not only potentially useful for fuelling the ambiguity characteristic of the grey zone, but are themselves vulnerable to exploitation by grey zone actors and tactics. For example, the drone can be used in plausibly deniable ways (an actor evading responsibility or accountability), but this plausible deniability can also be leveraged to justify actions in response to a drone incident or incursion. The drone's ambiguous properties contribute to grey zone ambiguity whilst at the same time grey zone ambiguity provides a rich context for the drone's ambiguous nature to flourish, creating a symbiotic relationship. However, the significance of recognising the drone's liminality goes beyond their use in grey zone and hybrid conflict contexts. The transitory nature of the drone – its existence at the edges of multiple thresholds – allows them to sit at the intersection of multiple uses and contexts, sometimes moving ambiguously between them. Of central concern, is that we are beginning to see the ambiguous effects of the drone's liminality permeating into domestic security settings. The multiple drone incidents at airports across Europe, and notably Gatwick Airport in 2018, stand as important examples of this (see section 4.1.2). Crucially, in observing instances of drone-induced ambiguity in non-conflict security settings, further weight is added to the assertion that ambiguity pertaining to drones is not solely the remit of subthreshold or grey zone conflict contexts. The drone possesses a distinct set of intrinsic properties that elicit ambiguous interpretation. It is the drone's design – its flexibility of application, multifaceted capabilities, and cyber foundation – that imbue the device with an inherently ambiguous quality – not always tethered to the scenario within which it operates. It is an active participant in the production of ambiguity surrounding its use, and the conceptualisation of the drone as a liminal system encapsulates this dynamic.

This chapter ultimately argues for an understanding of the contemporary drone as an inherently ambiguous device. Analysis throughout this chapter exposes the drone as a device whose essence is pluralistic, spanning a multitude of uses, operators, domains, and functions. These pluralities foster ambiguity, generating a web of potential interpretations around drones and their use in different contexts. In reimagining the drone as a liminal system, we can begin to better conceptualise this technology's capacity to traverse not only physical domains, but also thresholds and intersections of

uses, contexts, and perceptions. Liminality rests at the heart of the drone's character and can be leveraged and exploited in and beyond the context of conflict. This conceptualisation goes beyond the oversimplifications of drones and their relationship to ambiguity in existing literature. Indeed, by ascertaining this more granular understanding of the drone and its relationship to the phenomenon of ambiguity, we can begin to tease apart the properties – both technical and non-technical – that render certain tools or techniques effective in the generation of ambiguity. This is useful not only to help us mitigate or lessen the effects of ambiguity, but also for understanding future trajectories in the design and development of drones which may ultimately seek to exploit these features further through intentional design. This notion raises critical questions about the implications of such developments for security and conflict going forward, and as the disruptive device that is the drone converges with other technological developments. These questions are explored in later chapters. In producing an initial mapping of the drone's plurality and its association to ambiguity, this chapter paves the way for the next two research chapters which turn to explore in greater detail two of the primary properties identified here as central to the phenomenon of ambiguity and the drone: the adaptability of drones, and their inherent roots in the cyber domain.

5. Drone Plasticity and the Shaping of Aerial Ambiguity

Drones are highly versatile. This is a technology that can operate in a multitude of operational environments and for a variety of applications. These characteristics have seen the adoption of drones grow across both the civilian and military domains. Chapter 4 highlighted the drone's adaptable nature as a key contributing factor to ambiguities pertaining to determining a drone's purpose, function and capabilities (See section 4.2). Indeed, drones can perform multiple roles, even within a single platform (multi-role), and they can be used in a variety of contexts, both military and civilian (dual-use). As Chapter 4 exposed, this multiplicity can give rise to multiple plausible narratives pertaining to drone use, eliciting ambiguity as to its purpose and capacity. Yet, to end our inquiry of the drone's adaptability and its connection to ambiguity at this point would be insufficient. Drones are indeed adaptable, but this adaptability does not just happen – what properties allow, afford, or enable such versatility? This chapter sets out to explore this, moving from *extrinsic* perceptions of the drone's multi-role and dual-use nature to an investigation of the intrinsic properties and factors underpinning these attributes. By shifting the focus of analysis from external perceptions to an examination of the drone itself, a more granular understanding of what array of properties *enable* this adaptability can be obtained. The aim of this chapter is therefore to deepen our understanding of the constellation of material factors that contribute to both its adaptability and the resulting ambiguity.

Thematic analysis of data pertaining to drone adaptability and modification collected for this chapter (following the methods outlined in 3.4) reveals four primary themes: the drone's vast physical *mutability* through repurposing, ad-hoc modification, and increasing modularity; the physical transformation of drones through advances in *materials and morphing* technology; the capacity for *digital customisation* and reconfiguration; and the emergence of drone *self-adaptivity* with increasingly autonomous functionality. Each theme is presented in turn, drawing on examples from the dataset to support the discussion. First, *The Mutable Drone* (5.1) presents findings in relation to the primary ways in which drones can be physically modified for new purposes. From the repurposing of consumer drones for malintent, to structural modifications such as robotic arms, this theme explores the vast physical modification potential that enables the drone to be transformed for *new purposes and contexts*. Second, *Materials and Metamorphosis* (5.2) focuses on how drones can be modified or radically transformed in both physical form and materiality. Through an exploration of material advances and morphing drone technology, it explores the physical modification potential that facilitates the transformation of drones to *new forms*. Third, *Code Your Own* (5.3) explores the drone's capacity for digital modification. It focuses on the growing culture of software development kits in the consumer drone industry which empower users to alter, reprogramme, and digitally tailor a drone's *functions*. Further, it highlights how military drone software upgrade kits further expand the

capabilities of military platforms in ways that are often imperceptible; further contributing to ambiguity around knowing the capabilities of a drone system. Finally, *From Adaptability to Adaptivity* (5.4) focuses on the ways in which the drone is increasingly able to modify aspects of *its own* behaviour. From adaptive algorithms enabling the drone to respond to environmental change, to advances in swarming intelligence, it explores how autonomy transforms the drone's *capabilities.* Each theme reveals deeper associations between the drone's overarching adaptability and the phenomenon of ambiguity, with its vast modification potential adding layers of complexity to existing ambiguities arising in relation to determining the purpose, context, functions, and capabilities pertaining to their use.

Ultimately, the chapter introduces the concept of *Drone Plasticity*, a new conceptual lens for understanding the drone's inherent adaptability and its entanglement with ambiguity. The plasticity of drone technology manifests through processes of life cycle alterations, modifications, and transformations, all of which actively shape and reshape the material existence of the drone. In turn, these processes can influence the ability to determine with confidence the drone's capabilities, functionality, or operational role. This perspective allows us to understand the drone's dual-use and multi-role attributes as emergent properties arising from the dynamic interplay of the drone's underlying material plasticity, and comprising both its physical and digital modification potentials. The chapter argues that understanding the drone's intrinsic plasticity is crucial for assessing the complexities and emerging opacities that surround aspects of its use. Through its focus on investigating this spectrum of modification potential, this chapter reveals an array of extrinsic and intrinsic variables that contribute to drone adaptability, underscoring the drone's role as an active participant in the phenomenon of ambiguity.

5.1 The Mutable Drone

> With every modification comes a chance that a once-effective C-UAS solution is rendered useless at detecting, identifying, and defeating the UAS by the time it is fielded...
> - (Harmon, Holden, and Brandon 2016)

The drone is a technology of vast physical variety. We can observe drones of all shapes and sizes, and of varying configurations and designs (Gettinger 2019). The drone's physical diversity extends beyond shape and size, to other physical transformations. Physical transformation refers here to the range of ways a drone platform can be *physically modified* or changed. This section unpacks the first theme that emerged from the analysis of data collected for this chapter. It focuses on three key areas: the *repurposing* of drones; *morphing* drone systems; and *materials*. From the repurposing of

consumer drones for malintent and morphing drones that enable new capabilities, to material advances, this theme explores the *physical variables* of modification potential that enable the drone to be *externally* transformed for new forms, functions, and contexts. In so doing, it profiles the non-static nature of drone technology and queries the knowability of a device so amenable to change and transformation.

5.1.1 Repurposing and Physical Modifiability

The capacity for drones to be modified is part of their appeal. A drone can be modified to suit a specific task or purpose, but this trait also presents clear challenges for defence, security, and society. If the drone is continuously changing, how can we effectively defend against it? More specifically, can we ever truly know a drone's capabilities or purpose if the variables of its modification potential are continuously expanding? Drone innovation continues at an incredible pace, and options for drone modification are seemingly endless. Modification is defined here as an alteration made to a drone before it is deployed and in anticipation of its operational requirements. Modifiability, therefore, is understood as *the capacity for a drone to be modified*. This section does not attempt to present an exhaustive list of how one might physically modify a drone. Rather, it focuses on two prominent contexts in which we can clearly observe the drone's vast modification potential: the repurposing and weaponisation of consumer drones, and the structural modification of drones for new contexts or purposes.

Repurposing and Weaponisation of Consumer Drones

The modification of commercially available drones for malintent is something scholars such as Dunn warned about over a decade ago, well before we had observed this happening in the international arena (Dunn 2013). This prediction became a reality in late 2015 when the extremist organisation Daesh used a drone with concealed explosives to kill two members of Kurdish forces in Iraq (M. Schmidt and Schmitt 2016). Daesh have used drones since 2014, with the group reportedly using the commercially available DJI Phantom FC40 platform as a surveillance tool (Cenciotti 2014b). The transition to experimentation by the group with *physical* drone modification can be seen from 2015, when reports of the group using fixed-wing consumer drones with fuselages packed with explosives began to emerge (Hambling 2015). A 2016 investigation by Conflict Armament Research revealed a glimpse into the extent of Daesh's early drone experiments with modification. The team uncovered unassembled drone parts including wings, fuselages and electronic components, in addition to missile components that had been disassembled; an indication of the groups plans to experiment further with weaponisation (Conflict Armament Research 2016, 2). The group also experimented with modifying other drones including quadcopters and fixed swept-wing drones, and homemade drones of varying

configurations (B. Watson 2017). By early 2017, the group's capacity to modify and weaponise consumer drones had grown beyond earlier attempts as reports emerged of the group weaponising consumer quadcopters with home-made munitions in Iraq and Syria (BBC News 2017). By attaching an improvised plastic release mechanism to the underside of the drone, the group was able to weaponise the platform with 40mm munitions (see Figure 7) (Waters 2017).

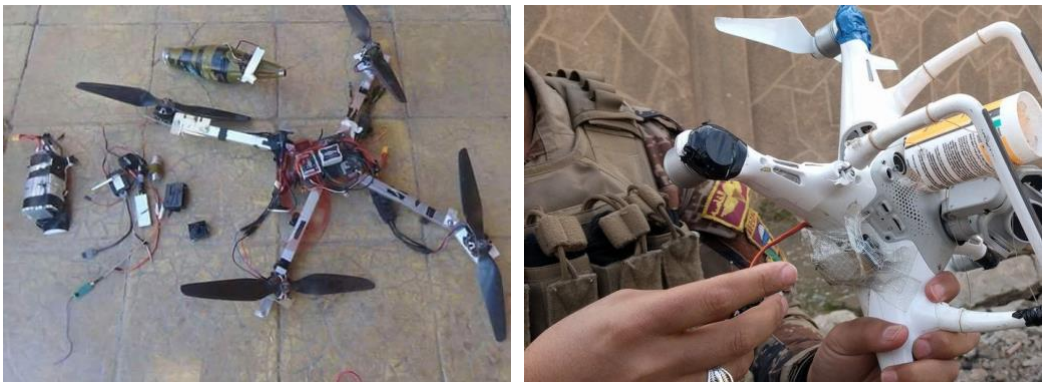

Figure 7. Modified drones of Daesh. Left: home-made quadcopter modified to carry RPG warhead. Right: consumer quadcopter with basic plastic cup holding mechanism for munition release. Photo Source: (B. Watson 2017)

The repurposing of consumer drones by Daesh is an important example because it highlights the technological and strategic surprise that the drone's capacity for modification affords. The weaponisation of consumer drones surprised U.S. and U.S.-backed forces in Iraq and Syria – they were simply not ready for it. It was described by a key official as one of the "most daunting" challenges troops faced in the battle for Mosul (Larter 2017). This pivotal moment in the evolution of drone technology and its use, sparked concern internationally (Velicovich 2017; Plaw and Santoro 2017) and saw the subsequent adoption of similar tactics by other violent non-state actors (Rogers 2019a; Plaw and Santoro 2017; Lasconjarias and Maged 2019). It is now widely acknowledged that drones can be easily modified to achieve military objectives or for other malicious purposes (U.S. Department of Defense 2021, 8; Chavez and Swed 2020; Vasilis and Martin 2020, 78). The small size, ease of modification, and accessibility of consumer drones has been noted as central to their adoption by non-state actors for malintent (Vasilis and Martin 2020, 79). Alongside their adoption by such actors, these features have also been recognised and embraced by state actors, with the increasing adoption of small consumer drones into military arsenals (Gettinger 2019). The problematic implications arising from the growing ubiquity of consumer drones across both the military and civilian spheres were raised in Chapter 4 – namely, the plurality of plausible narratives this creates as to drone ownership and use as the userbase increases (see section 4.2).

This ease of modification is further reflected in the smooth transition of civilian drones into security and military contexts. Indeed, drones originally created for the civilian sphere can be modified with relative simplicity to enable them for military applications:

> "Different procurement models exist for the small UAVs used by the defence sector. The easiest and cheapest way is often the acquisition of ordinary civil drones, which are upgraded to increase performance and/or signature control. Due to the rapid growth of the civil small-UAV sector, only a minority of models is developed for specialised military applications." (Blagoeva et al. 2019, 56).

Russia's invasion of Ukraine in 2022 has seen the use of consumer drones for military purposes explode (Hambling 2022). In such a conflict, where Ukraine lacks a sufficient aerial capability to effectively take on Russia's assault, both military grade drones and commercially available platforms have played an important role. The dual-use nature of the drone has been called upon, with calls for drone enthusiasts and hobbyists both in and beyond Ukraine to donate their civil drones to the war effort (BBC News 2022). Star Wars' Mark Hamill became the face of an international drive to raise money for the purchase of ten RQ-35 reconnaissance drones for Ukraine with the tagline "these are the drones you are looking for" under the United 24 initiative (United24 2022). The use and modification of consumer drones for military purposes has, however, caused some commercial drone companies discomfort. In the wake of Ukraine's use of consumer drones in its fight against Russia, Chinese drone manufacturer DJI issued a statement deploring the use of its products for military purposes. Specifically, it states the company has "…refused to customize or enable modifications that would enable our products for military use" (DJI News 2022). DJI's statement highlights the difficulty commercial and consumer drone companies have when it comes to control of their products post-purchase. Indeed, the vast modification potential of the drone – both digital and physical – gives manoeuvrability to those intent on modifying the platform regardless of company efforts to deter modification.

Structural modification of drones for new contexts or purposes

Physical modification of drones is not limited to lethal weaponisation. Aside from multiple options for modifying a drone's payload (see section 5.1.2), other physical modifications include the addition of attachments and appendages to tailor drones to different purposes. Most prominent is the addition of robotic arms to allow drones to grasp things. Such aerial manipulation seeks to combine the manipulation capacities of robotic arms with the flexibility of aerial platforms (Ruggiero, Lippiello, and Ollero 2018, 1957). The utility of unmanned aerial manipulators (UAMs) has potential advantages for those working in hazardous environments (Ruggiero, Lippiello, and Ollero 2018, 1961). Beyond the crucial distance that drones afford, UAMs offer advantages in both distance and *dexterity*, introducing their use to new contexts. The PD6B-AW-ARM developed by Japanese drone manufacturer PRODRONE is a key example. According to marketing materials, the drone is equipped with dual-robotic arms enabling it to conduct "hands-on operations" including attaching things together, pressing switches, cutting wires, and operating dials (PRODRONE 2016). Further to

dexterity, drone appendages such as claws and arms can also enhance the platform's manoeuvrability. Researchers at Stanford University developed the "stereotyped nature-inspired aerial grasper (SNAG)", a robotic set of claws that can be attached to drones to allow them to grab, catch, and perch (Roderick, Cutkosky, and Lentink 2021).

Such modifications can thus not only modify the drone to a new range of tasks, but also expands its manoeuvrability. A drone with the ability to perch introduces an array of operational advantages that a clawless drone could not offer. Perching is being explored to expand the operational range of drones to overcome battery limitations, such as the "passive perching" mechanism developed by researchers in Switzerland. The group designed the mechanism to enable a drone to perch on "largescale linear infrastructure" such as bridge trusses (Stewart et al. 2023). Drones with the ability to climb or cling to surfaces may further expand the realm of possibility in terms of operational reach and the spatial contexts where aerial drones can reach The reported use of a wall-climbing drone in training exercises by the IDF is one example (Hambling 2020c). Promotional footage of this "Urban Assault Drone" shows it fly up to a wall, attach itself to it, and then flip backwards, exposing an arm underneath attaching it to the vertical surface (Ari Gross 2020).

Physical drone modifications such as repurposing, ad-hoc weaponisation, and the addition of appendages and manipulators highlight the drone's amenability to post-creation alteration from external input. Each such change can enable new functions for the device, altering the scope and context of its applicability. In turn, this plays into the generation of multiple possible narratives pertaining to drone use – where due to the sheer number of ways drones can be used, certainty around what they are being used for is diminished. Yet, we are also seeing this amenability to alteration being readily *built-in* to the drone, rather than post-hoc alterations to existing platforms as explored here. It is this increasingly modular design of drones that we explore next, which emerged as a sub-theme in the dataset.

5.1.2. From Modification to Modularity

'Interchangeable', 'modular', 'plug-and-play' – these are terms increasingly used in relation to drone design and development. Efforts to produce expensive, multi-mission capable systems are ebbing away, and a shift towards a modular approach to drones has emerged. This shift is not happening in a vacuum, it emerges against the backdrop of a broader shift towards modular approaches in the military context over the past few decades (Kitchens et al. 2012). Modularity is a concept found in general systems theory. Schilling and Paparone offer a useful definition:

> "Modularity…it is a continuum describing the *degree to which a system can be separated and recombined*, and it refers to both the tightness of coupling between elements and the degree to

> which the *rules* of the system enable (or prohibit) the mixing and matching of components' capabilities." (Schilling and Paparone 2005, 281)

This mix and match element of modularity is echoed in the U.S. Army's understanding of the term, referring to is as "restructuring the force to produce a supply of direct interchangeable units" (Kitchens et al. 2012, 2). Similarly, the U.K's use of the term highlights that "[f]ormations and units are designed to be modular and scalable, so that elements can be easily added or taken away, and they can be expanded or contracted." (U.K. Ministry of Defence 2017a, 7–4). Interchangeability and reconfiguration sit firmly at the heart of modularity. The pursuit of these traits has bled beyond military formations and units, to the technologies and tools they use, and the acquisition strategies to procure them. Indeed, the U.K's Future Force Concept notes the adoption of modular approaches as key to increasing acquisition agility amid the rate of technological change (U.K. Ministry of Defence 2017b, 13). While exploring the broader trend of modularity is beyond this work's scope, this section seeks to explore how modularity manifests in proximity to the drone, interrogating what this shift means for the drone's *already* vast modification potential.

Modularity in the context of drone technology is noticeable in the rapid emergence of 'plug and play' payloads for drones. These are payloads that can be quickly and easily switched on the drone to suit a particular mission. The emergence of increasing modularity in drone design denotes a subtle yet important step-change in the evolution of the drone's modifiability. Rather than the drone simply being an object that can be externally modified by attaching something to its exterior (as the previous section explored), *modularity* illuminates the shift towards that modification potential being *purposely built into* the drone's design from the offset. Modular drone designs allow and facilitate the smooth transition from one payload to another – the drone platform is thus *designed* with modification potential in mind from the start. This stands in contrast to modifications such as repurposing, ad-hoc weaponisation, and post-device creation add-ons executed on platforms that were not originally intended for such modifications. This section focuses our attention on the ways in which the drone's emergence as a modular and rapidly interchangeable device reflects a partial *internalisation* of the device's modification potential. While still very much being an external form of modification in that – at present – a human typically has to swap the payload, modular drone design takes us a step further towards that modification potential becoming internalised and inherent to the device.

The pursuit of increasingly modular drone systems is evident when looking at drone development initiatives such as the U.S Air Force's Skyborg program. Skyborg aims to produce cheap drones with autonomous capabilities that can act as a force multiplier when teamed up with manned aircraft (Air Force Research Laboratory 2019c). BAE writes of the system, "[t]his modular and common system approach provides the foundation for rapid updates and integration to ensure the fleet is fielding the latest capabilities to defend against emerging threats." (BAE Systems 2020). Modularity is seen here

as the key to unlocking the ability to quickly and efficiently update the capabilities of the system. This understanding of modularity is reflected elsewhere. The UK Ministry of Defence's "many drones make light work" initiative demonstrates an interest in unlocking the potential of modularity in the context of drone swarms (U.K. Ministry of Defence 2016). It calls for "concepts that allow different platforms, with different performance characteristics, to be assembled just before a mission". Furthermore, it describes an interest in understanding the utility of swarms in relation to disaggregating multiple capabilities across multiple platforms; a concept termed in the document as '*fractionation*':

> "Fractionation is when you split up a capability or system normally carried by a single platform across multiple platforms, to reduce the size of the required platforms and achieve enhanced system-of-system effects." (U.K. Ministry of Defence 2016)

This concept of fractionation goes hand in hand with modularity, but it also goes a step further. Rather than solely thinking of modularity in terms of a single drone platform with the capacity for swift payload changes, fractionation of capability denotes modularity at scale – where each drone within the swarm has a different payload, different capability, and different task within the wider mission. This introduces the potential for a swarm of drones to theoretically possess (in the eyes of an adversary) an *unknowable set of capabilities*. As the ad-hoc and assembled nature of the swarm presents the possibility for multiple configurations and multiple capabilities, capacities to determine with confidence what any one drone within the swarm is tasked with and capable of decreases.

In the consumer drone context, Delair's DT26 open payload drone is a notable example of modification potential built-in to the drone design from the offset (Delair 2022). The drone's "integrate your own payload" design features a removable payload container allowing operators to put together their own preferred sensor suite to fit their specific needs. Again, in the context of being able to determine with confidence the capability or purpose of a drone in flight, such initiatives invite ambiguity. The shift towards modularity does not end at payload modularity. The drone is becoming more modular even in the context of its physical form. Auterion Government Solutions and Quantum-Systems developed two drones that can use a common sensor package and fuselage, yet operate as either a trirotor aircraft (Scorpion) or a fixed-wing aircraft (Vector) (Atherton 2020). The designs are also compact enough to fit into a rucksack. The adaptability such modularity enables is significant:

> "Adapting the fixed-wing fuselage to the tri-copter attachments means the drone can now operate in narrow spaces and harsh conditions. Scorpion, with the rotors, can fly for about 45 minutes….Put the fixed wings back on for Vector, and the flight time is now two hours…" (Atherton 2020)

We can thus observe modularity occurring at several levels in relation to drone technology. In terms of the drone's interchangeable payloads; in terms of the drone as part of a wider system of multiple drones itself being the modular system; and in terms of the drone's interchangeable fuselages making the drone's physical structure potentially interchangeable. This latter point hints at some of the more dramatic aspects of modification potential related to the drone's very structure. The next section, Materials and Metamorphosis offers a closer look at such structural modifications.

5.2 Materials and Metamorphosis

Physical alterations such as interchangeable payloads, ad-hoc weaponisations, and the addition of attachments only scratch the surface of the drone's vast physical modification potential. The drone is not only emerging as a changeable and non-static device in terms of its interchangeable payloads and other alterations post-device creation, but also in relation to its very materiality and form. This section introduces findings pertaining to developments in morphing drone technology and material advances in drone design, both of which are poised to add further complexity to our comprehension of this device and its use.

5.2.1 Morphing Drone Systems

When we think of a drone, generally there are two distinct types that first spring to mind: the larger class of military drone such as an MQ-9 Reaper (U.S. Air Force, n.d.); or a smaller consumer quadcopter such as those from DJI's Phantom series (DJI, n.d.). Sitting at opposite ends of the spectrum when it comes to visual appearance and capability, both have become synonymous with the word drone as we currently know it. However, drone technology is in flux. The drone is a platform that lends itself to change, advances in morphing drone technology stand as a good example of just *how* changeable this technology is becoming. Throughout the data collection for this chapter, a recurring theme was that of scientific and technological endeavours to extend the capabilities and manoeuvrability of drones through various physical changes to the drone's structural design. The physical morphing of drone hardware, or 'hard morphs' as they will be termed here, are pushing drones to new levels of versatility. From 'extendable wing' (Ajanic et al. 2020) and 'flapping wing' drones designed to improve flight endurance and performance (de Croon 2020), to hybrid drones able to traverse between different domains (Horn et al. 2020), the drone as we currently know it is shifting.

Morphing drones are those which can alter their shape, structure, or configuration during flight to increase performance (Hassanalian, Quintana, and Abdelkefi 2018, 78; Barbarino et al. 2011). Morphing drones often take inspiration from biological creatures like birds which are able to 'morph' their wings into different shapes to adapt their flight in relation to the environment around them (J.

Zhang et al. 2022; Tanaka et al. 2022; Lentink 2014). Organic life has provided scientists with a variety of tried and tested biological mechanisms, aesthetics, and behaviours to emulate in drone technology to improve aerodynamic performance (Fish 2020; Ben-Moshe et al. 2018; J. Zhang et al. 2022). While the wider domain of biomimetics is a fascinating area in relation to drone technology, this section is primarily concerned with physical structural *morphing*. Morphing-wing drones are a key example. Such drones have been under development for years and are typically explored as a way to increase drone flight capabilities including endurance, efficiency, and manoeuvrability (Özel, Özbek, and Ekici 2020). Morphing-wing drones involve the ability for the drone to lengthen, shorten, or adapt the configuration of its wings to suit flight or mission requirements. For example, Hui et al's bio-inspired morphing drone uses a skeleton structure inspired by pigeon wings, enabling the drone to deform its wings into different postures (Hui, Zhang, and Chen 2019).

Beyond morphing-wing drones, other designs facilitate the alteration of the drone's entire structure and dimensions. A 'morphing and growing' drone concept where the drone's overall dimensions can be altered proposes advantages such as extending the drone's range, endurance, performance, and stealth capability depending on the mission needs (Hassanalian, Quintana, and Abdelkefi 2018, 131). The researchers describe such a drone as possessing the features of "two different classes of drones", with the capacity to switch between them (Hassanalian, Quintana, and Abdelkefi 2018, 145). Morphing thus holds the potential to not only alter the wing-span of a drone but to alter the very scope of the drone's physical size and form. While this technology is nascent, the notion of a drone being able to transition between drone classifications via an alteration to its size, performance, and any respective increase in payload capacity, raises some interesting questions. For instance, how would the ability for the drone to transition between classes affect drone regulation, norms of use, or defensive strategies and decision making relating to identifying a drone's remit or capabilities. Morphing-wing developments are not limited to extendable wings, but also other wing alterations to improve performance. The U.S Air Force Research Lab developed the 'Variable Camber Compliant Wing', enabling the aircraft to morph the wing camber to suit different aerodynamic conditions. The aims of the design are to increase fuel-efficiency, manoeuvrability, and range of the aircraft (Air Force Research Laboratory 2019b).

Further to morphing wing platforms, the pursuit of mission flexibility through morphing can also be observed in the increasing drive for compact drones that can be folded, taken apart, or assembled when needed. Drones with folding features can be observed in both the military and civilian contexts. The ZALA 421-24 quadcopter developed by Kalashnikov subsidiary, ZALA AERO, is described as having a "compact foldable design" (ZALA AERO, n.d.). Skydio's X2 system boasts "foldable arms for easy portability" (Skydio 2022a). The company's defence version of the foldable platform, the X2D, was selected by the U.S. Army to fulfil its Short Range Reconnaissance program with a contract

value of $20.2 million (Skydio 2022b). WingXpand's drone stands as another example of this shift towards more compact platforms. It is designed with expandable-wing technology allowing it to be collapsed to fit into a rucksack and assembled when needed (Reed 2022). Further compact-folding drone examples include a plethora of consumer models such as Parrot's ANAFI Ai drone platform (Parrot 2021a), and DJI's foldable revamp of its Mavic platform (Heater 2022). Beyond folding to make the drone more compact and portable, foldability as a feature is also something being explored to allow the drone to fold during flight to alter its capabilities. Falanga et al developed a morphing quadcopter that can fold its rotor blades into different positions during flight, allowing it to navigate narrow environments (Falanga et al. 2018). Similarly, Bucki et al developed a quadcopter able to reconfigure its arms using unactuated hinges, enabling the drone to navigate narrow spaces, perch, and even grasp (Bucki, Tang, and Mueller 2022). This particular example highlights an interesting overlap between morphing capabilities and aerial manipulation research as discussed in the previous section; where the morphing mechanism *itself* can be utilised as a way to carry out manipulation tasks such as perching/grasping rather than having to add an appendage to the drone such as a robotic arm or claw.

The increasing move to more flexible airframes, both in relation to extending/morphing wings, and folding/compact drones is driven by the desire for operational and mission flexibility. Further to developments in structural morphing in the pursuit of flexibility, the metamorphosis of the drone does not end at its structural form. The very *materiality* of drone technology is also undergoing a quiet transformation in relation to the types of materials being used to create them.

5.2.2 Materials

The pursuit of flexible airframes has significant overlaps with the development of flexible *materials* for drone design and production. The advent of 3D printing has introduced incredible innovations in manufacturing. This is no less true in the sphere of drone technology. 3D printing, also known as Additive Manufacturing, is a process through which layers of plastic are built up to form a design or structure using a 3D printing machine (Ngo et al. 2018). The process is touted as a key technology that may prove intrinsic to unlocking the drone's full potential. A prime example here is the promise held by 3D printing for advancing the types of morphing drone technology discussed in the previous section. The process enables lightweight and flexible structures to be printed and used for morphing and flapping wing drones (Goh et al. 2017). Possibilities for 3D printing to be used in the creation of different smart materials ideal for morphing drone designs are also being investigated (Goh et al. 2017, 147). The promise of 3D printing for drones does not end with morphing. Perhaps the most interesting aspect is the use of 3D printing to print spare or replacement parts for broken drones as well as drones in their entirety (Busachi 2017). 3D printing offers flexibility in terms of *material*

flexibility (furthering morphing), but also in enabling the rapid printing of drone parts *in situ*, the process holds vast potential for increasing *operational flexibility* too.

Defence organisations have long sought to unlock new levels of mission flexibility through 3D printing, as seen in defence solicitations and competitions from over the last ten years. DSTL's additive manufacturing competition, for example, sought to explore 3D printing to "rapidly build, adapt or modify equipment to provide enhanced functionality" (U.K. Ministry of Defence 2014). The aim was to develop methods enabling the rapid assembly of components to create tailored "micro vehicles" for different missions. Such approaches are seen as a way to inexpensively introduce more flexibility in response to changing warfare requirements and operational environments (Costello 2015; Hammes 2016). Similar efforts can be seen in U.S. defence, where the Army and Marine Corps have collaborated to explore on-demand 3D printed drone parts (Lumb 2017). The ultimate idea was to develop a catalogue of software from which troops could select and print a drone depending on their specific mission requirements (McNally 2017). The 'Nibbler' was the first 3D printed drone to be both printed and used in a conflict environment, demonstrating the potential the capacity to rapidly 'print' a situational awareness advantage when needed (Eckstein 2017). As the desire for affordable and expendable drones expands, 3D printing offers a way to expedite the deployment of cheap drones en-masse and on-demand. In recent years, the Royal Air Force trialled the 'Pizookie' drone, a twin jet 3D-printed drone, in drone swarm trials, with officials noting the advantage of printing drones *as and when required* rather than in case they are required (Sprenger 2022).

3D printing is not exclusive to highly sophisticated state actors. It is a highly accessible and instructions for printing drones can easily be found online (Davey 2022). As 3D printing is adopted more widely, accessibility to drone technology may increase. This raises questions that link to the key themes of ambiguity and ubiquity discussed in Chapter 4. The sheer ubiquity of drones, coupled with 3D printing, magnifies the *plurality of plausible narratives* surrounding drone use in unique ways. Changes to the drone's material production to accessible methods like 3D printing introduce complexities regarding traceability, regulation, and attribution. Parts printed for drones, or entire drones, may be difficult to trace. Liability challenges pertaining to defective products that include third-party or outsourced 3D printed components are acknowledged (Harris 2020). Moreover, the possibility that 3D printed parts may be compromised exists, adding further complexity to attribution and liability (Graves et al. 2018, 45). One study demonstrates the feasibility of sabotage attacks in 3D printing manufacturing of drone propellers, where attackers were able to gain access to and compromise the rotor blade stereolithography (STL) files so the produced product was more likely to break when used (Belikovetsky et al. 2017). While important to note that drones are not the only device that can be 3D printed, an endless list of objects are amenable to 3D printing, including guns

(Chase and LaPorte 2018), the drones amenability to such processes further highlights its vast physical modification potential. The materiality of the drone is changeable.

Furthermore, the concept of the device itself is not a static one. Other material variations in the design and production of drones can elucidate this further. DARPA's 2015 call for the development of "disappearing delivery vehicles" that disintegrate upon completion of a mission is a prime example (DARPA 2015). The Inbound, Controlled, Air-Releasable, Unrecoverable Systems (ICARUS) program is the resulting initiative seeking to realise the vision of the dissolving drone (Margaritoff 2017). While much was written about this project at the time, publicly available information on the project's status is now as elusive as the concept of a disappearing drone itself. Similar concepts include a disposable origami style drone made of cardboard that will biodegrade upon completing its mission (Ferrell 2017), and Amazon's patent for "self-disintegrating drones" that can break up into smaller fragments if the drone malfunctions so to cause less damage when it falls (United States Patent US9828097B1 2017).

3D printing encapsulates a material shift in the drone – from a physical device that must be purchased, to a device that can be physically printed out. Furthermore, the notion of disintegrating and biodegradable drones encapsulates a deeper conceptual and material shift – from a device whose physicality is *permanent*, to a device whose physicality is *temporary*. What is interesting about these shifts, is its inherent entanglement with challenges of attribution, certainty, and thus ambiguity, raising new questions about their impact on such issues. As the drone shifts to both new material states, and new states of impermanence, ambiguities surround them may increase.

Taken together, section 5.1 and 5.2 present explorations of *external capacities* for the drone to be physically modified. They reveal the vast modification potential underpinning the notion of the drone – a highly variable object. Once a modification has been made, such as the addition of a release mechanism to the drone for a home-made ammunition, or addition of a robotic arm, the drone's scope has been altered. It may now be able to do new tasks in different contexts. Following modification, the very *possibility* of what the drone can do has been irrevocably changed – not only physically, but conceptually. This can be understood as a *plastic*, *permanent* alteration; even if the physical alteration is reversed, the conceptual scope of possibility surrounding the drone's abilities has been irrevocably altered. Such plastic changeability holds implications that feed directly into the concept of ambiguity. This will be explored and elucidated in greater detail in section 5.5.2.

5.3 Code Your Own

> Anybody with an internet connection can create their own drone…
> - (Tucker 2016)

The drone has its roots firmly in the digital realm. Without its digital foundation, and more specifically its cyber foundation the drone as we know it today would cease to function (see Chapter 6), The digital dimension of the drone introduces further variables of modification potential. In shifting our focus to digital aspects, the unseen modification potential that resides within the drone is revealed. In contrast to physical modifications, digital modifications are often imperceptible. This section focuses on two key areas related to *external capacities* to digitally modify the drone: the increasing ability for users to customise drone software; and drone upgrade kits that demonstrate continual enhancement of capabilities through software upgrades. Both aspects reaffirm our developing view of the drone as a system of continual change, not only at the physical level, but also the digital level.

5.3.1 Software Customisation

Empowering users with the ability to re-programme their drone offers flexibility in how it can be used and operated. This trend is noticeable in relation to consumer drones, where Software Development Kits (SDKs) are growing in popularity. As with modularity increasingly being *designed into* drones (as discussed in 5.1.2), the scope for customisation is also being designed into drone technology.

SDKs involve a set of software tools allowing developers to enhance and add functionality to a digital platform (Rosencrance 2019). For drones, SDKs offer a way to expand the functionality and user control over the platform, for example, through creating customised drone control apps (Davies, n.d.). SDKs are of interest because of the operator-empowerment they enable. They put more control in the hands of the operator, who can use SDKs to customise the drone's functionality and behaviour to their own requirements. Drone manufacturers are increasingly providing SDKs and promoting open-source development for people to write their own custom code onto drones. The ANAFI Ai drone by French company Parrot is one such example. The tag line for this drone reads: "Write code. Build apps. Create Missions. Fly drones!" (Parrot 2021b). Two SDKs are available for ANAFI Ai, the Air SDK and the Ground SDK – each offering developers ways to customise the drone. The Air SDK enables users to tailor drone behaviour by accessing its sensors, autonomous features, and connectivity interface. This allows users to create custom flight missions, add onboard processes and alter the guidance mode (Parrot 2021a, 23). The DJI Matrice series offers another example of this trend in the commercial drone sector, which has an onboard SDK, payload SDK, and mobile SDK allowing

different customisations (DJI, n.d.-a). The onboard SDK allows the tailored development of many features including flight control, obstacle avoidance, and pre-defined missions (DJI, n.d.-b). The payload SDK enables users to integrate a range of both dedicated and third-party payloads to "maximize the potential of your payloads in more diverse scenarios" (DJI, n.d.-a). A final example is the Ehang Falcon B series, described as "highly adaptable and extensible" due to the open SDK it offers (Ehang, n.d.). The use of the term *extensible* is fitting here. In computing, extensibility means the architecture of the system is *designed* to facilitate the easy modification and extension, without the necessity for substantial alteration to the existing codebase (Lacroix and Critchlow 2003). The Falcon B's open SDK is designed to facilitate the 'rapid development of new application scenarios based on specific industry requirements' (Ehang, n.d.).

The emergence of SDKs and open-source development in the commercial drone sector indicates a shift in how the drone is being conceptualised. Rather than a conceptualisation of the drone as a fixed device with a pre-defined scope of built-in capabilities, functionality, and applications, the drone in the age of SDKs is simply a frame, a body on which one can *build-on and develop* their own capabilities and functionality for a plethora of different applications. The growing SDK phenomenon can also be viewed against the backdrop of the broader shift to modularity explored in section 5.1.2 The digital modification potential introduced through open-source SDKs allows for various configurations of capability and behaviour to be assembled and modified in a tailor-made way depending on the mission requirements. The intentional designing-in of extensibility through open-source SDKs thus marks a further shift towards the internalisation of modification potential in the context of the drone.

5.3.2 Military Drone Upgrades

Military grade drones are frequently modified to enhance or expand their capabilities. This offers further insight into our understanding here of the drone as a technology with a multiplicity of modification variables.

Defence contracts for drone modification kits offer us a glimpse of this. A modification kit in this context refers to a package of capability enhancements which can comprise both digital and physical elements. These are typically ordered based upon military operational requirements and contracted to defence companies who deliver these capability enhancements in the form of modification kits. Key examples include contracts for supplemental hardware modification kits for the MQ-1C Gray Eagle system to extend its range (U.S. Department of Defense 2017). Extended-range modification kits comprise hardware upgrades allowing the drone to carry external fuel pods, enhancing its range

(Keller 2018). Others include modifications to communications, radar modification kits, Block 5 kits, and beyond line-of-sight kits (U.S. Department of Defense 2019; 2018).

Modification kits are not unique to drones, upgrade and modification kits for fighter jets and other weapon systems are customary (Allison 2021). However, modification kits in the context of the drone are of particular interest to our developing understanding of the drone in contemporary conflict, as they are yet another element of modification potential that sits around it. This growing list of modification variables plays into the ambiguity dilemma introduced in Chapter 4. Modification kits hold the potential to add to ambiguities around the drone's capability at any given time, particularly in the eyes of an adversary. Two states utilising seemingly identical drones could, in theory, be employing systems with greatly diverging capabilities. This raises important questions pertaining to the drone's knowability, where multiple possible and plausible narratives of capability and use are elicited consequent the drone's vast modification potential.

5.4 From Adaptability to *Adaptivity*: The Self-deterministic Drone

> …the drone can successfully navigate in complex environments.
> - (Devos, Ebeid, and Manoonpong 2018, 707)

The drone's modification potential explored so far have focused on the drone's capacity to be *externally* modified. Physical modifications including material and structural design, and digital modification through software customisation require input from an external user, designer, or developer. Certain external modifications show a subtle shift towards the *internalisation* of modification potential; payload modularity and the integration of open-source SDKs denote a shift to the *intentional facilitation of modification* within the drone's design. However, a more *intrinsic internalisation* of modification potential rests in the drone's capacity to modify *itself,* without external input. This section focuses on the drone's capacity for self-modification, exploring how increasing autonomy introduces different levels of self-determined behaviour. In considering the drone's ability to dynamically adapt to its environment, it reveals an intrinsic plasticity – showcasing the drone's capacity to internally alter aspects of itself.

Adaptability is defined as the capacity for something to "adjust to new conditions or situations, or to changes in one's environment" (Oxford English Dictionary 2023a). The term is often used to describe both the drone's capacity *to be* adapted (i.e., adapted by someone for a new purpose) and its capacity *to adapt* (i.e., adapt itself to new conditions or situations). The duality of meaning behind 'adaptability' is important but is often lost or overlooked. The difference in meaning is integral, as

one definition clearly denotes autonomy, the drone's *own capacity* to adapt to situations, where the other definition does not. The term adaptability can therefore be problematic and confusing when trying to delineate differences between the drone's ability to adapt itself, or to be adapted by something external to it. A useful distinction between adaptability and adaptivity can be found in the field of engineering and is hereafter adopted throughout this work: "While adaptivity is characterised by system-initiated changes, adaptability implies an interaction initiative of the assembly operator." (Burggräf et al. 2021, 224). This research thus uses the term *adaptivity* to denote the drone's capacity *to adapt itself* to new conditions or environments. The shift from external capacities to modify the drone to internal capacities of the drone to modify itself reflects a shift from adaptability to *adaptivity*.

Autonomic computing refers to systems with the capacity to manage themselves (Yahya, Yahya, and Dahanayake 2013, 235). Schmeck et al explain autonomy as a spectrum, with systems fully controlled by a user having no autonomy, and those that are entirely self-governing having full autonomy (Schmeck et al. 2010, 1). According to Gao et al, autonomous functionality in drones can be split into ten categories: "remotely guided, real time health/diagnosis, adapt to failures [and] flight conditions, onboard route replan, group coordination, group tactical replan, group tactical goals, distributed control, group strategic goals and fully autonomous swarms" (Gao, Zhen, and Gong 2016, 229). Increasing levels of autonomy mirror efforts to increase mission flexibility through modularity. The ethos of flexibility through modularity can also be observed in the different configurations of autonomy and control emerging in drone design. Northrop Grumman's Firebird is one example, available in "manned, autonomous and optionally piloted configurations" (Northrop Grumman 2021). Two areas related to autonomy, however, which were most prominent in the dataset for this chapter relate to the drone's ability to adapt to its environment, and advances in drone swarming.

5.4.1 Responding to Environmental Change

Obstacle avoidance, on-board flightpath re-routing (Singh et al. 2020, 231), and adapting to flight conditions (Hassanalian, Quintana, and Abdelkefi 2018, 145) are examples of the drone's ability to modify or adjust its behaviour to manage external change. These features represent an *internalisation* of the drone's digital modification potential. An external individual is not involved in such adaptive responses, the drone – through its autonomy – exercises self-determination to modify its behaviour by itself. These alterations, it must be noted, occur within set parameters and are relative to the design limitations of the device – both of which are ultimately designed/set by an external individual, at least in current drones.

Successful navigation of complex environments is necessary for drones to safely carry out tasks and avoid accidents. Obstacle avoidance is an important feature enabling the drone to map its

surroundings, detect obstacles and respond accordingly. Dushime et al highlight the necessity for drones to navigate two sets of obstacles: static, non-moving objects; and dynamic, moving objects that might appear suddenly (Dushime et al. 2021). Many approaches to obstacle avoidance exist, including sensing function approaches, conflict detection, escape trajectory, and geometric guidance approaches (Dushime et al. 2021, 1154). When an object is detected by the sensors, data is received by the flight controller which - through an obstacle avoidance algorithm – adjusts the drone's path to avoid it. This process overrides manual control of the device from the operator to avoid the object (Ciobanu, n.d.). This stands as an example of internal modification of the drone's behaviour, controlled by an algorithm. While an external individual created that algorithm, once running on the drone, the drone requires no external input from an operator to avoid the obstacle. An extension of this concept is found in notions of *threat avoidance* in military drone systems and concepts. This can be seen in early conceptualisations of advanced combat drones, where target identification and threat evaluation algorithms are envisioned as key to ensuring survivability of advanced combat drones in contested airspace (Franklin 2008, 5).

While obstacle avoidance is a common feature in high-quality drones today, research to improve this technology continues against the backdrop of an ever-increasing demand for drones to operate more autonomously and in more complex environments. In this context, Devos et al present an adaptive obstacle avoidance algorithm designed for an autonomous drone navigating complex environments (Devos, Ebeid, and Manoonpong 2018, 707). The algorithm is based on a recurrent network with *synaptic plasticity*:

> "By applying synaptic plasticity to the control network, the short-term memory will be regulated online during the interaction between the drone and the environment. This temporal memory regulation leads to optimal turning behaviour to avoid obstacles, corners, and deadlocks in different environments."
> - (Devos, Ebeid, and Manoonpong 2018, 708)

Synaptic plasticity in artificial neural networks is inspired by biological neurological dynamics. Its use in relation to drones offers insights for our ongoing exploration of modification potential. The broader concept of plasticity as it pertains to the brain is defined as: "the capacity of the neural activity generated by an experience to modify neural circuit function and thereby modify subsequent thoughts, feelings, and behavior" (Citri and Malenka 2008, 18). More specifically, *synaptic* plasticity refers to a learning phenomenon where synaptic connections strengthen or weaken in response to how much they are used. Kiranyaz et al sum this up well: "…the connections between nerve cells in the brain are not *static* but can undergo changes, so they are *plastic*.' (Kiranyaz et al. 2021, 7997). Emulating the dynamic properties of biological synapses in artificial neural networks facilitates

continuous local learning. As drones advance and become capable of increasingly autonomous operation, *plasticity* in the system design is essential.

Digital adaptivity extends beyond behavioural changes, to physical modifications of the drone. It is at this intersection that the drone's internal modification potential (adaptivity and self-determinism) meets the drone's external modification potential (external, structural modification). The AFRL camber morphing wing drone discussed in section 5.2.1 is one example. This system has the capacity to react to different aerodynamic conditions and morph *itself* according to those conditions to optimise its performance (Air Force Research Laboratory 2019a). Another example stands in BAE's Adaptable UAV concept, where the drone would be able to alternate between fixed-wing and rotary-wing flight depending on aerodynamic conditions using adaptive flight control, guidance software, and advanced navigation (BAE Systems 2017). We can thus observe situations in which the *internal* modification capacity of the drone can begin to exert control over aspects of the drone's *external form* and functionality.

5.4.2 Swarming: Self-adaptive and Self-organising Systems

Advances in swarming technology further exemplify the internalisation of the drone's modification potential. The concept refers to multiple drones that can coordinate and collaborate to achieve a shared goal (Kallenborn and Bleek 2018, 523). It offers vast potential for revolutionising how drones can be utilised in both civilian and military contexts (Innocente and Grasso 2019, 81). In the military context, swarming has long been considered a game-changing capability (Scharre 2014). A swarm's capacity to respond to changes rapidly, dynamically, and beyond the capacities of human response times is central to this (Scharre 2018, 387). Additionally, swarms comprising multiple individual drones working together offers a resilience that singular platforms do not; if one drone is lost, the remaining swarm adaptively responds to that loss, continuing its mission relatively unaffected (Lehto and Hutchinson 2020, 330). This self-adjusting capability showcases the drone's growing potential to autonomously adapt and change their behaviour and configuration, adding further perspective to our understanding of the drone's capacity for internal modification.

Swarm intelligence, a branch of AI, is at the heart of swarming technology (Tang, Duan, and Lao 2023). While several approaches to it exist, biological swarm intelligence takes inspiration from the natural world, where characteristics of flexibility, self-organisation, distribution and robustness can be found (Tang, Duan, and Lao 2023, 4297). Scientific models of these biological traits are used to produce algorithms which can reproduce these features in artificial systems, including drones (Bonabeau, Dorigo, and Theraulaz 1999, 41). In a swarm intelligence system, the agents that comprise it act autonomously and respond to dynamic changes in their environment without needing

centralised control (Schranz et al. 2021, 3). Such systems can be considered *self-adaptive*, having the capacity to alter their behaviour or configuration to manage changes around them (Moreno et al. 2017). It is within the context of swarms that we can further observe the concept of biological plasticity holding potential to expand the drone's modification potential. Hunt proposes that the phenomenon of 'phenotypic plasticity' holds value for improving swarm responses to environmental changes and for diversifying swarms to make them more resilient (Hunt 2020, 2). He notes: 'Plasticity can be introduced through the greater use of adaptive threshold-based behaviours; more fundamentally, it can link to emerging technologies such as smart materials, which can adapt form and function to environmental conditions.'(Hunt 2020, 1)

Research seeking to leverage both physical and behavioural heterogeneity in robotic swarms may offer further flexibility to swarms going forward (Dorigo, Theraulaz, and Trianni 2020, 1). For example, members of the swarm could be equipped with different hardware to carry out different tasks (physical heterogeneity) and be digitally specialised for different roles (behavioural heterogeneity). The notion of heterogeneous swarms begins to demonstrate the convergence of the drone's physical and digital modification potential explored throughout this chapter. As Dorigo et al note, such swarms are typified by the "morphological and/or behavioural diversity of their constituent robots" (Dorigo 2013, 61). A move towards such swarms – where assemblages of different agents are configured both physically and digitally differently for the execution of *dissimilar* tasks - epitomises the notion of modularity explored in section 5.2. Yet, it goes a step further by expanding modularity across the entire swarm system, rather than to a singular modular device.

The increasing autonomy in drones reflects a deeper internalisation of its modification potential and adds a further dimension of distance between the operator and the device. As drones gain more self-determinism, their functions, capabilities, and purpose become more complex to determine – not only to external observers, but potentially also to those operating them. As previously established, it is not always easy to determine the capabilities of drones or their purpose. Autonomy adds to this ambiguity. Determining whether a drone is being actively piloted, or whether it is operating autonomously is not simple to ascertain, further clouded by emerging capacities for drones to switch between modes as previously noted. Further, concepts such as heterogeneity in drone swarms introduces a high level of ambiguity in such systems. A heterogeneous swarm comprising agents with diverging capabilities and payloads means it could simultaneously carry out multiple roles, including kinetic strikes and digital attacks in addition to ISR. Such disaggregated and multifaceted functionality would make it more difficult to anticipate and respond to counter a swarm's actions. The continual evolution of drone technology is adding layers of complexity to our understanding of them. Rather than adding more clarity to conflict and security contexts through the situational awareness

advantages they offer, the drone's integration with AI and its subsequent autonomy adds new dimensions of ambiguity and uncertainty to this landscape that we are not prepared for.

5.5 Drone Plasticity

The drone's extensive modification potential – both physical and digital – adds layers of complexity that deepen its opacity. Building on the multi-role and dual-use nature of the drone identified in Chapter 4, this chapter moved to examine the properties that *allow, afford, or enable* such versatility. In doing so, it moved away from *extrinsic* perceptions of the drone's multi-role and dual-use nature, and towards the *intrinsic* properties and factors affording the device these attributes. Accordingly, it sought to establish a material understanding of the properties inherent to drones that facilitate its capacity to *produce plural narratives* surrounding their application, capability, and use. This chapter exposes the sheer scale of possibilities for drone modification across both the extrinsic (external/physical hardware) and intrinsic (internal/digital software) levels. Importantly, it highlights how drone modification goes beyond external alteration, considering the device's growing capacity to *internally modify* aspects of their own behaviour through autonomous functionality. The scope of the drone's modifiability introduces the possibility for ambiguity and even *unknowability* regarding aspects of the drone's functionality – even to those operating them.

This concluding section gives an overview of key findings before positing an understanding of the drone's versatile character as symptomatic of a more foundational property inherent to the device – that of the drone's *plasticity*. It subsequently abstracts a new conceptualisation of the drone's vast capacity to be modified, establishing an understanding of the drone as an *intrinsically plastic device*.

5.5.1 Opacities at the Nexus of Drone Modification

The drone's vast modification potential introduces an inherent pliability to the drone post-device creation. While other scholars working on drones have drawn our attention to the drone's versatility and malleable nature (Jackman 2019), existing conceptualisations around drone modification have yet to capture the full extent – and ramifications – of the device's pliability. The drone demonstrates wide capacity for extrinsic and intrinsic modification – a spectrum of modification potential requiring an evolution in our thinking around this device. Indeed, the drone can be externally modified, from the repurposing of drones, the structural and material modification of them, to intentionally modular designs facilitating easy alteration of payloads. The drone can also be internally and digitally modified. From Software Development Kits allowing for bespoke customisations to a drone's code and resulting functionality by individuals (*extrinsic* digital modification), to increasing levels of autonomy facilitating self-deterministic modifications related to a drone's behaviour and function (*intrinsic* digital modification). Through its focus on investigating this spectrum of drone modification

potential, this chapter informs the development of a different way of conceptualising drone modification: in terms of the *extrinsic* and *intrinsic* variables spanning both the physical and digital dimensions of the drone. Extrinsic variables of modification potential refer to the capacity for the drone to be *externally modified* by an individual in various ways (this can be both physical modification such as repurposing, and digital modification such as customising aspects of the drone's software). Intrinsic variables of modification potential relate to the capacity for the drone to *internally modify itself* (e.g. modification of its own behaviour or physical form in response to external stimuli).

This extrinsic-to-intrinsic exposition of the drone provides an important material understanding of the device's modification potential. This conceptualisation goes beyond current explorations of drone modification, adding a depth of understanding that encapsulates the continuum of potential from the outermost aspects of modification to the innermost ones. In this way, we can map drone modification from the tangible to the intangible, paving the way to better assess the implications that stem from differing modification pathways. Developing a more nuanced understanding of this continuum is increasingly important as the drone continues to evolve and collide with other technologies in new ways. While versatility surrounding drones often garners widespread acknowledgement, there has been little focus in International Relations and Security Studies regarding the extensive ways drones can be modified, the factors underpinning this, and the broader implications of such modification for defence and security. The strategic implications of the drone's capacity for modification has remained largely limited to their repurposing by terrorist groups and other rogue actors (Sims 2018; Cronin 2019; Hastings-Dunn and Wyatt 2018; Ball 2017; Plaw and Santoro 2017; Rogers 2019a; Abbott, Clarke, and Hickie 2016; Chavez and Swed 2020; Chávez and Swed 2021). Consideration of wider political and strategic effects of drone modification has largely eluded the literature both in International Relations and the wider drone discourse.

This chapter builds on Chapter 4, elucidating how the drone's capacity for vast modification interacts with the phenomenon of ambiguity. It demonstrates how ambiguity related to capability, purpose of use, and operator identity may be exacerbated through modifications across the extrinsic-intrinsic nexus. The capacity for external modification such as ad-hoc weaponisation introduces *multiple possibilities* as to what a drone might be capable of or used for. In addition, material shifts in the production of drones – such as 3D printing – introduces further ambiguity by contributing to attributional challenges. Furthermore, the capacity for internal modification also introduces multiple possibilities as to a drone's functionality and capability. This chapter produced the following mapping of the drone's modification potential and its association to ambiguity as shown in Table 3.

Table 3. The Intersection of Drone Modification Potential and Ambiguity.

Factor Contributing to Ambiguity	**Description**	**Resulting Ambiguity**
Ease of Ad-Hoc Modification	Ad-hoc weaponisation, the addition of third-party or improvised payloads, and the increasing trend of payload modularity.	Heightens ambiguity surrounding a drone's functionality, capability, purpose, and context of use due to the multitude of potential uses across various contexts.
Production Using Alternate Materials	Use of 3D printing and other alternative manufacturing techniques.	Increases ambiguity regarding attribution, creating multiple plausible owners and origins and raising questions around traceability and identification.
Digital Customisation	Software development kits, open source code, and update kits.	Heightens ambiguity pertaining to a drone's capabilities. It introduces vast scope for tailored and customised variation that may affect the device's capacities and functions.
Self-Determinism through Autonomous Functionality	The capacity for autonomous behaviour modification	Introduces ambiguity around a drone's level of intelligence and thus its capabilities. Operational intent and functionality may be unclear.

Understanding the properties inherent to and surrounding specific tools or technologies allows for a deeper understanding of what makes them apt for such use. We can begin to piece together the underlying components and dynamics that contribute to practices of drone use and their adoption. This holds importance for understanding current uses of technology and the effects they can produce. Further, it elucidates the finer dynamics of these effects, which may help ascertain better methods of mitigation and provide insights into future trajectories of technology design, adoption, regulation, and use.

It is within this context that Cronin makes an important contribution with her theory of lethal empowerment (Cronin 2019). She presents a framework that helps us determine technologies more likely to be adopted by violent non state actors, bringing to light key attributes making certain technologies appealing, including being "accessible, cheap, concealable, multi-use, easily combined with other technologies, and given to unexpected uses" (Cronin 2019, 257–58). However, a comprehensive exposition of these features in relation to the technologies she explores is missing, including in her analysis of drones. This is where a comprehensive mapping of the drone's modification potential actively demonstrates its value, exposing a more granular understanding of the tangible factors underpinning the attributes that scholars such as Cronin only scratch the surface of. In stopping short of attending to the 'how' and 'why' questions, Cronin's assessment provides an

incomplete reading. This chapter assists in illuminating the 'how' and 'why' underpinning some of the attributes surrounding drone technology adoption that Cronin explores. Crucially, exposing these layers allows us to explore how this translates in terms of its effects, and how it influences drone use or adoption both operationally and strategically.

5.5.2 The Drone as Plastic Object

This chapter illuminates an expansive assemblage around the drone's versatility, encompassing its hardware, software, userbase, operational environments, and broader forces such as the military-industrial complex, which drives innovation to allow for increasing mission flexibility in drone use. By bringing into focus the drone's capacity for vast modification, this chapter reveals some of the underlying properties of the drone's amenability to a plurality of purposes, functions, and uses. This concluding section builds on these findings to establish a conceptual understanding of the drone as possessing an intrinsic *plasticity;* referring to the pliability of the drone post-hoc device creation, driven by its digital foundation, operational context, and experience of the device.

This plasticity can be understood – to follow Bennett - as a *function of the interactions* within the broader assemblage of the drone's versatility, where each component contributes to the evolving capabilities and roles of drone technology. In turn, each plays a part in amplifying the drone's capacity to 'act' through the number of possible narratives pertaining to drone use that can be generated (Bennett 2010).

The notion of drone plasticity leans on two definitions of plasticity. In biology, plasticity refers to the alteration of cells or organisms consequent of changes in their environment (Skipper, Weiss, and Gray 2010, 703). More specifically, it has been used in neurobiology to refer to alterations in the nervous system consequent of changes in the "internal or external milieu" (Huttenlocher 2009, 3). In mechanics, plasticity deals with "the calculation of stresses or strains in a body, made of ductile material, permanently deformed by a set of applied forces."(Chakrabarty 2006, 1). Both uses of the term are central for contemplating drone modification and the ambiguities this gives rise to. Plasticity is conceptualised as an inherent property of the device that engenders its dual-use and multi-role nature, which can be seen as emergent properties. Drone plasticity encompasses two aspects: *extrinsic plasticity* – encompassing the device's permanent deformation through external modification of varying kinds both physical and digital; and *intrinsic plasticity* – encompassing the drone's capacity to self-modify in response to external stimuli (See Table 4). This understanding of drone plasticity yields a new lens through which to analyse the resultant ambiguity.

Table 4. The Concept of Plasticity: Extrinsic versus Intrinsic

Plasticity	Description	Example
Extrinsic	Refers to the permanent deformation of a drone through external capacities of modification. Extrinsic plasticity is not determined or controlled by the device itself but requires an external 'modifier'.	Physical repurposing of the device through weaponisation, external structural alteration, alternative material production. Digital modification through software customisation and updates.
Intrinsic	Refers to the capacity for a drone to modify aspects of itself in response to changes in its environment (both external environment and system-level environment). Intrinsic plasticity is determined by the device itself.	Self-modification of behaviour (e.g. obstacle avoidance), functionality (e.g. task), or structure (e.g. wing shape) determined by the device itself in response to external stimuli in its operational environment.

The plasticity of the drone introduces ambiguity by obscuring abilities to confidently determine the function, capability, and operational role of a device. This understanding positions plasticity as a critical factor in the ambiguity associated with drones. The concept is neatly exemplified by consumer drone technology and its vast modifiability. In relation to consumer off-the-shelf drones, Jackman highlights the necessity for broader consideration of the drone's malleability in relation to "function, form, application and purpose." (Jackman 2019, 15). Indeed, understanding the varied and evolving capabilities of consumer drones is central to considerations related to associated future risks, threats, and opportunities. While Jackman's malleability concept effectively captures the pliability of drones in relation to potential uses, forms and functions, it falls short of encapsulating the deeper, more indelible changes that occur over a drone's lifecycle. Nor does it attend to the internal life of the drone at the intrinsic level, taking into consideration its capacity to self-modify and what this means for its capacity for modification. Drone *plasticity* fills these crucial oversights in the conceptualisation of the drone's modification potential, emphasising that each change – whether in form, function, software, operational context, or experience of the device – leaves an indelible mark from which the drone cannot return. Unlike malleability, which implies a flexibility or elasticity that is temporary – where a drone can return to an original state or form after modification – plasticity denotes a more profound, permanent alteration. Once altered, the drone cannot simply revert to its previous state. It is here that the concept of drone plasticity leans on the biological notion of brain plasticity, where alterations in the "external or internal milieu" (changes in the internal environment of the body or external factors) influence how the brain fundamentally functions, adapts, and develops (Huttenlocher 2009, 3). We can conceptualise the drone's extrinsic and intrinsic plasticity in a similar way. Consider, for example, a drone that undergoes a software update. Software updates provide enhanced features such as in-flight stabilisation, enhanced speed or manoeuvrability, adaptive obstacle avoidance, and increased range of control. These digital alterations change the device's operational logic, producing a new operational baseline that the drone cannot 'unlearn' or revert from. It is a *plastic* change, not an elastic

change. Physical alterations to the drone also leave lasting, indelible traces on the drone's operational capacity and identity. By fitting advanced imaging sensors to a drone, its physical capabilities are altered. Such changes fundamentally alter the device's role and, importantly, its range of *potential uses* in a way that cannot be undone. Even if the sensors are removed, the very *possibility* of its advanced sensor capability remains to those perceiving it.

The notion of permanent alteration encapsulated in drone plasticity extends beyond immediate changes in form and function. It encompasses the very identity of the drone itself, fundamentally altering how it is perceived and understood within differing contexts. Catherine Malabou's work on pathological destructive plasticity provides a useful anchor for situating drone plasticity in relation to the phenomenon of ambiguity and the drone as an active participant in the production of it. Malabou theorises that accidents in life produce a phenomenon of plasticity; a plasticity that "does not repair", that "cuts the thread of life in two or more segments", or makes an entity unrecognisable from its former self by "impos[ing] a new form on their old form."(Malabou 2012, 6). The emergence of the consumer drone resonates with this notion; a critical juncture in the lifespan of the drone where it was severed from its original form or original use in the military sphere. Through the emergence of consumer drones, the concept of the drone had a new form imposed upon it; a technological, material manifestation of Malabou's phenomenon of destructive plasticity. The consumer drone as both object and concept was irrevocably altered as the notion of the "rogue drone" came to exist the very moment violent non-state actor groups weaponised them (Watson 2017). This modification created a permanent and indelible mark on the very identity of the consumer drone, which suddenly became a possible vector for violence. It altered the collective perception of drones, influencing not only how we might inteprert them, but also influencing regulatory responses, security concerns and developments, and the public discourse on drone use. We can observe documented examples of the very possibility of the consumer drone's weaponisation playing into existing public unease and uncertainty around their use (European Union Committee 2015; European Union Aviation Safety Agency 2021). Drone plasticity – through material, immaterial, and conceptual alteration, multiplies the number of possible narratives as to the drone's capability or function. This plays an active role in the compounding of ambiguities pertaining to confidently determining the purpose, function and capability of drones. To channel Bennett's notion of vibrant matter, the drone's plasticity imbues the device with a lively agency that interacts with the world around them, shaping and reshaping their context of operation and fundamentally challenging our understanding of the drone's role and capacities (Bennett 2004; 2010). Moreover, this plasticity is not limited to heightening ambiguity externally – that is, to those external to the device's operation. Rather, we can begin to conceptualise a dual-plasticity in the drone with its increasing autonomy, where facets of its function, behaviour, and capability may be ambiguous to both external parties *and those operating them*. In this sense, the

drone's plasticity allows it to act in ways that might not be wholly anticipated or controlled by their operators, further underscoring its latent agency.

The conceptualisation of drone plasticity presented here goes beyond current understandings of the drone's modifiability. It importantly encapsulates the digital, intrinsic modification potential tied to the drone's autonomy; modifications occurring independent of an external 'modifier'. This distinction is crucial, allowing us to comprehend the intangible and indelible modification taking place at the intrinsic level within drones and to consider its interactions with existing ambiguities arising in relation to the device. Existing literature has fallen short of producing a conceptualisation of drones that fully captures the drone's modification potential – or indeed its modification potential across both its intrinsic and extrinsic dimensions. The concept of drone plasticity addresses this, offering an understanding of drone modification that extends beyond the realm of external modification to encompass its emerging intrinsic potential for self-modification. Further, this conceptualisation contributes to our developing understanding of the drone as an inherently ambiguous device. Plasticity allows us to consider how alterations across the material, immaterial, and conceptual contexts of the drone play an active role in the continuous shaping of the device's roles, capabilities, and contexts of use. The drone's ongoing evolution, driven in part by this plasticity, lends the device to an ever-increasing number of identities and possibilities, further complicating capacities to define and determine their capabilities and functions. Going forward, the drone is likely to transform further through various technological and scientific advances. New critical junctures in the lifespan of the drone will impose new forms *and thus new narratives and possibilities* that further expand the plurality of possibilities – and therefore interpretations – already surrounding the device.

6. Cyber-Physicality: Manifesting the Digital in the Physical Realm

The drone represents a collision of the digital and physical realms. It is a device that entangles the tangible with the intangible, the material with the immaterial. In approaching the drone from a cyber-physical systems perspective, this chapter explores the relationships and associations between the drone's cyber foundation and the phenomenon of ambiguity. Building on the approach and research from Chapter 5, which explored the modification potential of drones from the extrinsic to the intrinsic, this chapter moves us closer to the drone's digital foundation. It seeks to ascertain how properties related to the drone's digitality interact with the phenomenon of ambiguity.

Through thematic analysis, this chapter discusses three main themes related to the drone's cyber-physicality and ambiguity pertaining to drone use: *intrinsic invisibilities*; *unbounded frontiers*; and the *cyber-physical nexus*. Each theme is presented in turn, drawing on examples to elaborate and explore the nuances between these themes and the phenomenon of ambiguity. Section 6.1 – intrinsic invisibilities – highlights some of the inherent challenges arising from the drone's cyber foundation. It delves into digital traceability issues, exposing how ambiguity around the integrity of digital evidence can exacerbate attribution problems. Further, it considers how the 'black box' nature of AI within drones may introduce new complexities to transparency issues, complicating understanding and trust in drone operations. Section 6.2 – unbounded frontiers – explores the idea of physical and digital boundary transcendence, reflecting on the drone's capacity to surpass traditional operational limits. It considers how emerging developments like the Internet of Drones (IoD) and Flying Ad-hoc Networks (FANETs) are placed to further their operational reach, introducing new layers of ambiguity in drone use. It also explores the drone's capacity to evade physical and regulatory constraints due its cyber properties, presenting challenges for accountability, attribution, and governance. Section 6.3 – the cyber-physical nexus – explores the complex interplay between the drone's cyber and physical aspects, highlighting their unique position operating across both domains. Drones can be used as vectors for both cyber and physical attacks and be targets of them. This adds layers of complexity to their use, producing ambiguities around drone capabilities and purpose of use.

By exploring the unique interplay between the drone's digital and physical realities, this chapter maps the drone's cyber-physicality to the phenomenon of ambiguity. It reveals how a range of factors contribute to conflicting interpretations as to a drone's operator, purpose, and capabilities, further solidifying an understanding of the drone as an inherently ambiguous device. Importantly, the chapter introduces the concept of *Remote Physical Presence* which encapsulates the drone's capacity to exert influence across both cyber and physical domains. It argues for greater consideration of the drone's capacity to function as a seamless extension of the cyber domain within the physical realm, highlighting the challenge this introduces to conventional notions of presence, and imbuing the device

with a novel form of agency to exert influence beyond traditional boundaries. This lens further illuminates the drone's agency regarding its capacity to generate ambiguity; where mere presence alone can act to cause disruption – untethered to the operator's identity, intent, or device payload. Ultimately, this chapter underscores the growing significance of an understanding of drones as inherently ambiguous actors, whose presence and plurality can be leveraged and exploited in ways that add new dimensions of ambiguity to the contemporary landscape of conflict.

6.1 Intrinsic Invisibilities

The drone is a device that fundamentally fuses the concepts of visibility and invisibility. A central appeal of this technology lies in its capacity to make visible to us what is normally beyond our reach, bringing more certainty and security through increasing situational awareness. The concept of visibility surrounds the drone and many of its uses as it allows humans to extend their vision beyond normal parameters (Marlin-Bennett 2013, 603). At the same time, the drone is surrounded by many *invisibilities*. Indeed, the lens of (in)visibility is a valuable apparatus to critically approach the drone. A significant body of work exists on the ideas of visibility and invisibility in the context of the drone (Grayson and Mawdsley 2018; Allinson 2015; K. Maurer 2016). This work lays an important foundation for the critical consideration of drone technology and the often-concealed processes and practices surrounding their use. For instance, Niva's work focuses on the less visible side of drone warfare, bringing to light the "shadowy" networks and structures underpinning such practices, demonstrating how they can be concealed from view and scrutiny (Niva 2013b, 197). Others have explored how drones can play a part in rendering certain *things* or people 'invisible', for instance, by making some groups more visible than others (Allinson 2015; K. Maurer 2016). Moreover, the work of Grayson and Mawdsley highlights the key role visuality plays in allowing us to understand how different "fields of vision" come into being through drone technology (Grayson and Mawdsley 2018, 3).

Invisibility was a recurring theme throughout the analysis of data collected for this chapter, which seeks to explore the cyber foundation of the drone and its association with the phenomenon of ambiguity. What follows is an exploration of the often-overlooked digital invisibilities inherent to drone technology, revealing insights into the intrinsic invisibilities embedded in the drone's very fabric. Invisibilities identified coalesce around digital traceability challenges and algorithmic opacity. This theme explores issues of data integrity, evidence extraction, and traceability within processes of drone digital forensics; exposing how it is not always possible to have full confidence in digital evidence pertaining to drones. It then explores algorithmic opacity in increasingly autonomous systems, focusing on the 'black box' of artificial intelligence and the ambiguities this gives rise to. The intrinsic invisibilities explored throughout this section assist in demonstrating the challenges and

ambiguities that can arise from the drone's digital foundation. Building on the work of the previous chapter, it further maps the intrinsic elements of the drone that contribute to its assembly as an ambiguous device, while providing new lines of inquiry for future research into the drone's relationship with the concepts of (in)visibility, transparency, and opacity.

6.1.1 The Digital Unseen: Forensic Traceability Challenges

Chapter 4 highlighted the challenge of anonymity in the context of drone use, identifying that a multiplicity of plausible narratives can surround the drone in certain situations (both civilian and military), giving rise to ambiguity in relation to the device's operator, operational context, and purpose. When the information landscape surrounding a drone and its use is incomplete, certain aspects of that drone's use or purpose essentially become 'invisible' to us. The drone's digital foundation is pivotal in the affordance of 'invisibility' pertaining to attribution. Attribution problems are typically associated with cyber operations, yet, it is a challenge inescapably inherited by the drone, consequent of its cyber lineage. This section adds to our inquiry of attributional challenges by taking us closer to the drone's cyber foundation. It finds that the soundness and integrity of digital evidence can be called into question in multiple ways, rendering vital information about a drone's activities, origin, or operator, inaccessible, ambiguous, or invisible. Further, it establishes an array of extrinsic and intrinsic factors contributing to attributional challenges related to the drone.

The ability to identify a drone's operator and trace other information such as flight log data, is of critical importance to incident response. The necessity of establishing robust accountability mechanisms for drone use is widely acknowledged, but key challenges in tracing crucial information needed for that remain. Addressing issues of traceability and anonymity in drone use has been highlighted as a key priority by the Department for Transport in the U.K. While the introduction of drone registration regulations has aimed to provide a partial solution, identification challenges remain (Department for Transport 2016, 5). Part of the drone's appeal is its accessibility, and not all drones will be registered. Unregistered drones pose a particular challenge to digital forensics. The near impossibility of identifying the operator of an unregistered drone absent the physical drone itself has been recognised (Altawy and Youssef 2016, 20). It has been suggested by some that the use of commercial drones is "digitally semi-anonymous" and that physical factors may be the best way to obtain evidence about a drone's origin, activities, or operator (Salamh et al. 2021, 9). Hartmann and Giles identify three factors complicating attribution in the context of drones. Firstly, the device may be unidentifiable due to having no associated ID. Second, the hardware may be identifiable but not attributable to a specific actor due to the ID not being registered, the device having been hijacked, logs manipulated or only partially accessible. Lastly, the operator may indeed be identifiable, yet

claim not to have been in control of the device (Hartmann and Giles 2016, 216). Such claims become plausible due to the digital properties underpinning the drone, which as we will explore, pose challenges for data integrity and accuracy.

Pieces of digital evidence from a drone can be useful for various aspects of a drone forensic investigation. For instance, data related to the payload and flight plan can assist in understanding a drone's purpose, while metadata and stored data including visual imagery could assist with attribution (Mantas and Patsakis 2022, 5). However, ensuring digital evidence extricated from a drone is accurate, reliable and trustworthy can be complex and difficult. In addition, there are multiple ways the integrity of digital evidence might be impacted before, during, and after extraction. The very act of digitally accessing and removing data from a drone can cause problems with digital evidence. For instance, researchers highlight that in drones where data is encrypted or where there is no storage device to remove, the data may need to be accessed via exploitation of a vulnerability. This can impact the stored information in significant ways and render it unusable in a court of law (Mantas and Patsakis 2022, 7). Even in situations where an unregistered drone *is* physically recoverable, extracting evidence can still present challenges, for example, with drones that do not have data logging capabilities. In such drones, flight log data is transferred and stored in the ground control station (GCS) not the device itself (Altawy and Youssef 2016, 20). It is here that we can observe the complexity that the larger 'system' *beyond* the drone presents in relation to attribution. The drone is part of a wider array of components, people, and objects coalescing in different ways to make the drone functional (human operators, internet infrastructures, software, hardware etc.). In relation to discovering digital evidence from a drone, other external components come into play, including unclear processes of evidence extraction, lack of standardised practices for drone forensics, and performance reliability of forensic software (Salamh, Mirza, and Karabiyik 2021, 733; Mantas and Patsakis 2022, 5). These are *extrinsic factors* feeding directly into attributional challenges related to drones.

When we begin to explore the various factors contributing to the complexity of attribution and traceability, a complex interplay of intrinsic and extrinsic factors emerge. Numerous problematic areas contribute to ongoing challenges of digital drone forensics, including the complexity of drone system architectures and their data flow mechanisms (Salamh et al. 2021, 4). Data flow refers to the way in which data is transmitted or transferred between components of a system. According to Salamh et al, the data flow in drones does not always trace identifiable information for several reasons. Of note here are challenges related to the customisation of drones, and the production of less secure drone systems that fail to adhere to basic security standards (Salamh et al. 2021, 9). Again, here we can observe extrinsic factors – customisation and design and manufacturing short-cuts – giving rise to intrinsic challenges linked to attributional issues. Lack of security features in

commercial drones is a good example. Mantas and Patsikas sum up the significance of lack of authentication and encryption on commercial drone products: “Due to their absence, the received commands are not authenticated, and their source can be questioned. Therefore, it is not evident who issued a command to the drone…” (Mantas and Patsakis 2022, 6). In such systems, doubt can be legitimately raised over who was in control of a drone in a given scenario, enabling a level of anonymity and deniability around its use.

Forensic analysis software itself can present issues in relation to data integrity. An experiment by Salamh et al illuminates a key challenge when decrypting drone flight logs. In running the same drone flight log twice using a particular software – DatCon on a Java virtual machine (VM), two different outcomes were produced due to a technical issue which compromised the data integrity (Mantas and Patsakis 2022, 11). The second run failed to produce the same cryptographic hash value, a vital requirement for ensuring the integrity of data across both attempts.

Table 5. Multiplicity of decryption process, adapted from Salamh et al (2021), A Comparative UAV Forensic Analysis: Static and Live Digital Traceability Challenges.

Decryption Process	File	Size (bytes)	MD5 Hash Value
Attempt 1	*FLY000.CSV*	*32,978,802*	*2601969f36bd0d59d1cc3624361c5730*
Attempt 2	*FLY000.CSV*	*32,908,703*	*ee36a352c4052c080796096dc470406e*

While important to note that this experiment’s outcome derived from a technical issue occurring with a specific software set up, it highlights the potential for *plurality* in the results of digital forensic investigation of drone data and the possibility of multiple interpretations being induced by that.

6.1.2 The Manipulation of Visibility

The drone itself can be made ‘invisible’ courtesy of its digital foundation. With particular focus on spoofing and obfuscation, this section demonstrates the pliability of the drone’s cyber fabric; a property that can play a part in rendering a drone’s true location, or even existence, unknown or uncertain.

Many drones use a GNSS (Global Navigation Satellite System) such as GPS (Global Positioning System) for navigation, guidance, and positioning (S. Z. Khan, Mohsin, and Iqbal 2021). GPS spoofing involves the broadcast of fabricated signals to a targeted GPS server to deceive it into accepting those signals as authentic (Psiaki and Humphreys 2016a, 1258). The purpose of which includes manipulating vital navigational and positional data such as position, velocity and time (Kerns et al. 2014, 617). The ease of achieving such an attack on civilian GPS, which lacks encryption and authentication, is widely acknowledged (S. Z. Khan, Mohsin, and Iqbal 2021; Su et al. 2016;

Eldosouky, Ferdowsi, and Saad 2019). As is the susceptibility of GPS-dependent drones to spoofing attacks. The purposes for conducting a GPS spoofing attack on a drone can include forcing the drone to deviate from its intended flight route, all while appearing to be exactly where it should be (S. Z. Khan, Mohsin, and Iqbal 2021, 2). This deceptive form of attack allows the nefarious actor to take control of the device in a way that is masked by false positional and temporal data. To the target operator of a spoofed drone flying beyond line of visual sight, their drone may appear as though it is still on course, yet the physical device may be in a different location. The implications of this can pose significant problems as both the validity and integrity of GPS signals become uncertain.

The pliability of digital data fundamental to the drone's functioning – such as its location information – plays a crucial role in this discussion of invisibility. Obfuscation as it relates to cyber security means to make something (usually data or code) difficult to understand or interpret. This is usually for the purposes of safeguarding personal or sensitive data (Xu et al. 2020). Obfuscation techniques to safeguard a drone's location data provides an interesting insight to further explore the drone's intrinsic (in)visibilities. In their work seeking to protect drones from privacy attacks, Naeem et al demonstrate the ability to transmit *modified location data* to a known attacker or intruder to conceal the drone's true location (Naeem et al. 2021). For drone forensics, the pliability of a drone's location data could significantly undermine efforts to piece together an accurate picture of a drone's flight path or its activities. If such data can be manipulated, confidence and trust in accurate conclusions drawn from the data becomes questionable and open to multiple interpretatios.

6.1.3 The Black Box: Algorithmic Opacity

The 'black box' of AI is a phrase increasingly common to hear as advances in AI surge. There are many unknowns surrounding the development, functionality, and use of AI. The lack of transparency associated with AI has garnered significant attention, with efforts to understand how to improve transparency around AI and its applications (P. Schmidt, Biessmann, and Teubner 2020; Felzmann et al. 2020; de Fine Licht and de Fine Licht 2020; Wischmeyer 2020). Similarly, efforts to make explanations of AI better as it evolves and becomes more complex to understand have also grown (Nagahisarchoghaei et al. 2023; Chinu and Bansal 2023). This section focuses on how the opacity related to AI interacts with drone technology; a device increasingly developed with varying levels of autonomy. Where the previous section dealt primarily with 'invisibilities' arising from *external* factors, we now move to look inward at the *intrinsic* invisibilities we can find in the very software and algorithms that contribute to the contemporary drone's functionality and behaviour.

It is useful to first ground our understanding of what is meant by algorithmic opacity. In computer science, algorithms are sets of rules or instructions for performing calculations and solving computational problems (Belford and Tucker, n.d.). Opacity is the quality of something lacking transparency. Algorithmic opacity, then, is defined by Paudyal and Wong as:

> "…a condition where algorithms lack visibility of computation processes, and where humans are not able to inspect its inner workings to ascertain for themselves how the results and conclusions were computed." (Paudyal and William Wong 2018, 2).

The appeal of AI rests in its capacity to unburden humans from having to carry out certain tasks, calculations or decisions, and the speed at which it can do so. Despite the opacity of algorithmic outputs, it has been noted their capacity to provide optimal solutions means they are still highly desirable (Gutzwiller and Reeder 2021, 854). Yet the advantages that AI promises have also given rise to much debate and concern. There exists a growing body of literature around the ethical, legal, and social implications of AI (Carrillo 2020; Karliuk 2018; Larsson et al. 2019; Cath 2018). Not least due to a sense of unease around what it truly means for humans to give up some of their agency to *artificially intelligent* systems. Nowhere has this been more evident than in the ongoing debate over the development of lethal autonomous weapons systems (LAWS) (Horowitz 2021; Sauer 2021; Longpre, Storm, and Shah 2022; Lele 2019). A central concern is the ethics and legalities associated with allowing machines to make life or death decisions, particularly if we do not understand *how* that decision was made. When aspects of decision-making are transferred to AI, attribution and accountability potentially become more complex. In discussing the existing use of military drones for targeted killing, Weiskopf and Hansen highlight the "find, fix, track, target, attack cycle", noting that it transfers responsibility to "procedures and machines."(Weiskopf and Hansen 2023, 494). This transfer of 'agency' to machines can be understood as a technical mediation of human cognition; one that presents complications for attribution and tracing responsibility (Hayles 2016, 34). Further to moral and legal questions around the transfer of complex decisions to machines, there is the issue of trust. If we cannot always understand how algorithms arrive at the decisions they make, how can we trust those decisions are accurate, or in the best interest of those they involve? Further, how can we fully *know* a system, or indeed its capabilities, if aspects of its functionality are opaque to us?

Hancock points out two key questions or concerns surrounding autonomous systems: "What is it doing now" and "what will it do next?"(Hancock 2022, 214). Both questions are pertinent here. Even before considering autonomy, the drone can already exude a sense of the unknown around its utility and purpose. As explored in previous chapters, with many variables as to a drone's functionality, capabilities, and context of use, it is not always easy to know what a drone is currently doing in a given situation, let alone what it might do next. When we add a layer of autonomy to this equation – a self-deterministic element – we are adding a behavioural dimension to the ambiguity around the

drone, courtesy of the drone's very software. We must now not only consider ambiguity arising around context of use and modifiability, but also a level of self-determinism introducing further scope for what a drone might do or be able to do.

A concern regarding AI and drones is the unpredictability this may inject into dynamics of drone use in conflict. The possibility for drones with high levels of autonomy to display non-deterministic or unpredictable behaviours is acknowledged (Matalonga et al. 2022, 9). Swarming technology – particularly algorithms designed for emergent coordination – is one example. While the set of rules (algorithms) being followed by each individual drone is simple, the interaction of multiple drones produces complex behaviours (Scharre 2019, 20). The speed at which they can react and coordinate adds further complexity. Indeed, the possibility that drone swarms will outpace human capacities to keep pace on the battlefield is a real concern (Hambling 2021). Hancock highlights the *temporal disconnect* between autonomous agents and human controllers: "…they live, work, act, and perform on increasingly disparate time scales."(Hancock 2022, 214). For Hancock, this disconnect may lead to what he terms "opaque interactions" between humans and systems with high levels of autonomy. The unknowability of some aspects of autonomous functionality (how it makes certain decisions), coupled with the temporal disconnect (algorithmic processes outpacing human cognitive processes), sees the dynamic between operator and system change. There are simply parts of the process in the drone's functionality that are unknown to us - opaque; inaccessible either through the invisibility of the algorithmic processes themselves or the sheer speed at which those algorithms are operating.

Burrell's work on understanding opacity in algorithms identifies three types of opacity arising in relation to machine learning (ML) algorithms: opacity as "intentional corporate or state secrecy"; opacity arising from "technical illiteracy"; and opacity pertaining to the "characteristics of machine learning algorithms" (Burrell 2016, 1). It is this latter category which is of most interest here. Burrell argues that it the distinct qualities of scale and complexity that give rise to the opacity of ML algorithms. Specifically, she notes that as algorithms learn on vast quantities of training data, their internal decision logic changes, resulting in the code becoming more complex. Furthermore, efforts to manage this complexity render the code even harder to understand (Burrell 2016, 5). The very nature of how the algorithm itself functions (taking in and learning from more and more data) makes it more complex and takes it that little further away from human understandability.

The integration of drone technology and AI enables drones to perform increasingly sophisticated tasks and navigate complex environments with minimal human input. It facilitates enhanced capabilities such as obstacle avoidance, real-time data processing, and adaptive flight path planning. Such enhancements are poised to offer increasing precision, manoeuvrability, surveillance, and situational awareness – capabilities which align with the broader narrative of drones providing increased

flexibility, clarity and certainty to conflict and security contexts. However, a key tension emerges between the promise of enhanced efficiency and situational awareness through AI-driven drones and the opacity of the algorithms enabling it. As the drone collects, processes, and learns from information in its environment, its internal decision logic is, following Burrell's argument, becoming more complex. This continual alteration of the drone's internal decision-making logic can be linked back to the concept of plasticity introduced in Chapter 5 – where permanent changes in the drone leave indelible marks that push it beyond our ability to fully know the device. AI-driven drones may thus contribute to a more ambiguous security landscape.

6.2 Unbounded Frontiers

Drones afford humans an extended reach, enabling access to areas too perilous or difficult to reach and facilitating action-at-a-distance. In doing so, they are a tool for the remote exertion of will. Indeed, the drone has been considered a technological augmentation of human senses, permitting us to *sense beyond* usual human and physical constraints (Marlin-Bennett 2013, 603). This reach has made drone technology a desirable tool across many civilian and military uses, but has also placed drones at the centre of much debate. The drone's capacity to conquer geographical distance and the problematic implications arising from this are widely noted in this regard (D. Gregory 2011b; J. Williams 2015; Coeckelbergh 2013; Kasachkoff and Kleinig 2018). The legalities and ethics of targeted killing from a distance also features heavily in these discussions (Chehtman 2017; Strawser 2013; J. Williams 2015; D. Brunstetter and Braun 2011a; Boyle 2015; 2018; Sterio 2012). Distance, is intimately tangled with drone technology in different ways. The drone's cyber foundation plays a central role in this story of distance. It permits the device's operator to push the boundaries and limitations of distance, time, and presence. The drone is a technology that seems to defy limitations. This section turns to focus on how the drone's digital dimension affords it the capacity to do so, exploring how the drone's digital fabric permits reach; one that goes beyond the geographic, pervading both the physical and digital worlds.

6.2.1 Cyber-physical Horizons

Drones allow one to extend their reach over a wider area than would normally be possible. Advances in the development of drones and the integration of AI is poised to increase this reach, introducing new options for scaling drone use to new levels. Linked to the realities of the drone's reach and increasing scalability is a sense of limitlessness, or endlessness to the device's capacity. Several scholars have explored the notion of boundlessness which captures aspects of the drone's vast reach in the context of conflict (D. Gregory 2011b; Holmqvist 2013; Chamayou 2015; Benjamin 2013). The idea that drone technology facilitates an endlessness to conflict, one that defies geographical limitations or seeming end points in time or space is a fascinating one. Gregory's acclaimed

'everywhere war' is a prime example (D. Gregory 2011b). Agius, as a further example, argues that a reliance on drones by the US and other countries has enabled war to become "unbordered and unbound by the constraints of sovereignty"(Agius 2017, 370). Moreover, Green and Bernal note how drones remove the limitations on "who may be seen as the enemy" as they traverse established international boundaries (Green and Bernal 2013, 215). The concept of boundlessness is a rich one, and holds relevance for this exploration of the drone's digital foundation, which itself displays properties of boundlessness.

The sense of an endless, boundless expanse of virtual 'space' is congruent with the intangibility of cyberspace. As with trying to imagine the vastness of the universe, trying to envision cyberspace as a tangible thing can be perplexing. Some have sought to establish frameworks for understanding the sheer scale of cyberspace (Jardine 2015, 3). It is this very issue that contributes to the complexities and difficulties at the heart of debates about cyberspace regulation (Mueller 2020). Similar intangibilities can be found in the context of drone technology. Underpinned by a vast digital fabric, the idea of 'boundlessness' resonates with digital aspects of the drone's functionality, operation and use. Here we explore the notion of the drone's *digital boundlessness*.

The reach of the contemporary drone is poised to extend as developments in concepts such as the Internet of Drones (IoD) come to fruition. The IoD is a "layered network control architecture" designed to support networks of drones in controlled airspace (Gharibi, Boutaba, and Waslander 2016). It is considered a potential gamechanger and is described by some as part of the coming cyber-physical system revolution (Salamh et al. 2021, 3). Application areas for the IoD span from supporting drone delivery services and search and rescue operations, to smart mobility, public communications, and environmental applications (Choudhary et al. 2018, 2). Choudhary et al sum up the concept well: "The IoD based technological revolution upgrades the current internet environment into a more pervasive and ubiquitous world." (Choudhary et al. 2018, 1) It is this very sense of ubiquity and pervasiveness that feeds into our discussion around the scale and reach of this technology, lending to a sense of digital boundlessness. Bolstered by the IoD – a fundamentally digital infrastructure – the drone's reach becomes somewhat multi-dimensional. For instance, consider drone devices linked via the IoD to other connected platforms and devices. Just as there is uncertainty over drones today as to whether they are collecting information and what the purpose is (see Chapter 4), in an IoD environment these uncertainties are scaled up just as the drones in the network are. Not only is there a question over what information a drone might be collecting and how that data might be used, but also a question regarding whether that data is being sent to other nodes in the IoD, transmitted or shared to other devices, and for what first, second, and third order purposes. There is thus an amplified set of unknowns around the collection, transfer, and exchange of data between nodes within a prospective IoD due to its extended connectivity and coverage. Boundless

possibilities, boundless plausible ways in which that data might be used or transferred, and a resulting multiplicity in interpretations.

Flying ad-hoc networks (FANETs) are similarly poised to extend the drone's reach and scope. A FANET is a type of network that enables multiple drones to communicate with each other regardless of whether they are heterogenous or homogeneous. Within the IoD, FANET zones can be established to support multi-drone networks, which are considered far more adaptable and scalable than single-drone networks (Tsao, Girdler, and Vassilakis 2022, 2). But as explored in Chapter 5, high levels of adaptability can introduce challenges (see section 5.5). Multi-drone networks such as FANETs can frequently change topology, meaning their form and configuration are non-static (Hayat, Yanmaz, and Muzaffar 2016, 2627). While the flexibility of a FANET is designed purposefully to allow versatility, this very flexibility introduces instability in the form of the network's changing dynamics. For example, movement between drone nodes in the network can lead to connectivity challenges (Hayat, Yanmaz, and Muzaffar 2016, 2628). Others have noted concerns about the military use of FANETs, highlighting that due to their operating autonomously, information about the status of a mission can be limited, with the potential for serious ramifications: "Simple programming ambiguities in such networks may result in unintentional causalities, injuries, or…damages of civilians instead of targeted terrorists."(Zafar and Khan 2016, 72). This relates back to our previous discussion of invisibilities and the opacity of algorithms. Both the IoD and FANETs are underpinned by algorithmic functionality.

As previously established, with distance can come a certain amount of ambiguity. The increasing reliance on algorithmic functionality in drones with higher levels of autonomy adds a different dimension to this distance-ambiguity relationship. In the quest to further extend human reach through concepts such as IoD and FANET, we are increasingly reliant upon algorithms to support the communications and coordination of those systems and architectures. In so doing, we are trading off aspects of *knowing*, and aspects of *certainty* regarding the very systems and internal processes we are relying on.

6.2.2 The Digital Expanse

The notion of digital boundlessness extends beyond the scalability of drones. It is in the context of drone digital forensics that Mantas and Patsakis highlight the "borderless" nature of data storage and its relevance to drone technology. If digital evidence from a drone such as flight log data or media files are stored on servers in third party countries, or in cloud-based infrastructure, access issues can present data sovereignty and legal challenges for investigators (Mantas and Patsakis 2022, 5). It is important to note here, that this borderless nature of data is not unique to *drone* data, it is a broader issue of the borderless nature of the internet and how data is transferred and stored (Svantesson 2007).

However, the reason it is interesting in the drone context is the additional layer of distance it constructs around the knowability of the drone or its circumstances. The remote nature of drone technology already places it at a distance from its operator. The borderless nature of data can place the operator and any other data about origin, purpose or owner at a further degree of distance depending on data privacy and international jurisdiction around where that data is stored. This poses obstacles to digital forensic procedures, with implications for being able to trace and attribute drone activities to accountable parties (Mantas and Patsakis 2022, 6).

The concept of digital boundlessness comes to life in a deeper way when we consider the capacity for drones to manoeuvre around digital defence mechanisms. Geofencing is a technique that uses GPS to construct a virtual fence around a geographic area and remotely monitors tracked objects going into and out of that perimeter (Reclus and Drouard 2009). Geofencing has become a common technique used to prevent unwanted drones from entering sensitive locations such as CNI and prisons (U.K. Ministry of Defence 2023). Geofencing is essentially an invisible barrier to keep unwanted objects out of a particular area, or within a given boundary. In the context of the drone, it places a limitation on where that drone is allowed to venture, seeking to curtail its spatial reach. However, geofencing can be disabled, circumvented, or hacked. Spoofing is one technique that can be used to circumvent geo-fencing (S. Z. Khan, Mohsin, and Iqbal 2021, 3). In this kind of attack, the drone would send out false location data so the geofencing software believes the drone's position to be somewhere else (Gaurav 2022). The usual geofence response (triggering of an alert or command for example) would therefore not be triggered by the drone's presence in the restricted area, allowing it to continue unobstructed. There is something interesting about this reality. In a spoofing situation, digital limitations such as geofencing *cannot contain* the drone, consequent of the digital foundation to which the drone is intricately bound. The pliability found in cyberspace allows for the digital defence mechanism to be circumvented. But what is most interesting here, is the interaction of this digital pliability with the physical world. The pliability or *plasticity* of the digital is directly enabling the physical entity of the drone to evade spatial limitations placed upon it. In other words, it is affording a level of pliability in the physical drone's spatial reach. In this sense, the plasticity of the digital (the very property underpinning facets of its boundlessness) is transferred to the physicality of the drone and its actions. The drone becomes a physical manifestation of digital plasticity, allowing it to operate as an extension of the cyber domain.

6.3 The Cyber-Physical Nexus

> …the physical domain and the cyber domain are bound together.
> (Wang et al. 2019)

Cyber physical systems (CPS) are computer systems which can interact with and affect the physical world through sensors and actuators (Alur 2015, 2). Drones are a prime example of CPS. While this understanding is commonplace in fields such as computer science, robotics, and more recently geography, drones are not traditionally analysed as such within the social sciences (Wang et al. 2019, 16). This is, however, not to overlook the various work on drones that has considered aspects of the technology's cybernetic dimensions, computer vision being a prime focus (Bousquet 2018; 2017; Wilcox 2016).

Deeper consideration of the drone's cyber-physical foundation is fundamental to understanding the complexities of the contemporary drone. In relation to understanding drones as CPS, Wang et al use the terms "cyber shell" and "physical entities" to capture the separation of the cyber and physical elements constituting drones (Wang et al. 2019, 16). The cyber shell encompasses computational components such as sensing, control, and communication. The physical entities comprise the foundational physical elements of the drone platform (actuators including motor, rotor, sensor units) and broader elements of the physical world (operational environment, humans, and machines). Only through the cyber shell – the *interface* between the cyber and physical domains – does it become possible for physical entities in the network to actualise information from the digital world; a process described as the binding together of the physical and cyber domains (Wang et al. 2019, 16). Drones represent this fusion of the physical and cyber worlds. While the link between drones and the cyber domain is not a new revelation, the nuances of this intrinsic connection receive insufficient attention within the drone discourse. We need only look to the vulnerability of drones to both cyber *and* physical means to underscore the centrality of the cyber-physical fusion at the heart of this technology – as explored in section 6.3.2 (Sanjab, Saad, and Başar 2020, 6990).

This section therefore adopts a more direct understanding of drones as CPS, illuminating the relationship between the drone's cyber-physical properties and how they interact with the phenomenon of ambiguity. It explores the challenges this cyber-physical fusion represents, beginning with an exploration of how it redefines human presence. It then moves to consider the drone's unique position at the cyber-physical nexus, exploring its duality as both an attack vector for physical and cyber attacks, and as a vulnerable target with an attack surface susceptible to attacks from both domains.

6.3.1 Cyber Physical Presence

Drones allow humans to extend their reach. This technology has afforded humans the ability to extend their sensing capabilities beyond the limits of physical bodies and beyond geographical boundaries. Marlin-Bennett, in discussing the technological mediation of human senses puts it eloquently: "We are hybrids; we are cyber-humans. As our senses reach out through cyber environments, we become (partially) what Jane Bennet, following Deleuze and Guattari, calls 'bodies-without organs'"(Marlin-Bennett 2013, 621). The drone further enables the extension of influence and control beyond borders without the physical risk attached to human physical presence on the ground. As Aguis notes, the drone facilitates the exertion of control over territories and populations in novel ways (Agius 2017, 371).

Drone technology mediates more than just our senses and capacity to influence from afar. The physicality of a drone platform carries with it a *tangible presence.* To channel Hayes, we can understand the drone not only as a mediation of senses or power projection, but a technical mediation of human presence (Hayles 2016). Drone warfare has been described by some as "absentee warfare", referring to the lack of troop presence on the ground, and lack of human presence on board the aircraft (Clark et al. 2018, 334). Similar conceptualisations are abundant in the literature, raising important questions about the use of drones in conflict and its broader implications (Knowles and Watson 2018; Gusterson 2016; Benjamin 2013; Coeckelbergh 2013; Gibson 2021; Wilcox 2015b). Yet, while the drone neatly exemplifies bodily *absence* in this respect, it simultaneously exhibits an inescapable *cyber-physical presence* – a presence that itself plays an active role in the novel capacities of influence and effect the drone can conjure.

When a drone is in flight, we understand someone is operating it for a particular purpose. While this identity and reason might not be clear, or even knowable – the implicit understanding that there is an operator and a purpose behind its presence has influence. It is in this sense that the drone 'acts' on its operator's behalf; a transferral of human presence - and agency – to the physical entity of the drone.

This powerful link between operator identity, purpose, and the transfer of agency to the drone produces a unique dynamic in which the operator's influence is amplified through the remote physical presence of the drone. The power of this transferral can be observed in the use of drones for monitoring purposes. It has been noted that such presence of drones can contribute to positive outcomes in peacekeeping missions, providing a deterrent effect against certain activities (Apakan and Giardullo 2020, 486). An example given is the use of drones to oversee financial transactions between non-government and government controlled areas in Ukraine to ensure it goes as planned. Such use for drones is described as "protection-by-presence"(Apakan and Giardullo 2020, 484–86).

The deterrent effect of drone presence is also noted in other areas, such as use of drones by anti-poaching teams (Penny et al. 2019). Conversely, drone presence can have negative effects in both civilian and military contexts. Koslowski and Schulzke discuss the use of drones in border security roles, noting that their presence and "upsetting" visual appearance might make borderlands more threatening (Koslowski and Schulzke 2018, 319). In relation to public acceptance of drones for logistics, Smith et al highlight some individuals perceived drones as "an unwanted physical presence or noise." (Angela Smith et al. 2022, 4). In the context of conflict, a large body of work has sought to expose the negative psychological, and other effects of drone presence (Emery and Brunstetter 2015b; Edney-Browne 2019). For Emery and Brunstetter, the presence of drones – its ability to loiter, surveil, and track – allows it to "occupy" the airspace, suggesting the *power* of such presence lies in the drone's capacity to strike without warning anywhere and at any time (Emery and Brunstetter 2015b, 425).

There is certainly power interlaced with drone presence in situations where one has some idea the drone belongs to a party engaged in certain activities, whether monitoring, tracking, or lethal use. What is less clear, is the interplay of power and presence in situations where one does *no*t know who is operating the drone or for what reason. Does drone presence still wield power? And if it does, where can we trace that power arising from? The cyber-physicality of the drone can offer an insight.

The uniqueness of cyberspace has been described as contingent upon it being at once actual – through the physicality of cables, computers and servers – and virtual, through its lack of a definite location or clear geographical boundaries (Cristiano 2018, 34). As physical entities inherently entwined with the cyber realm, drones too, can be understood in a similar way. In cyberattacks, however, an obvious, tangible *physical presence* at the site of attack is absent. In fact, the lack of physicality to cyberattacks have led some scholars, most notably Thomas Rid, to posit cyberattacks are unlikely to result in direct violence (Rid 2012, 9). A drone on the other hand, adds a kinetic, physical element in the liminal space between the physical and virtual. The drone diverges from a cyberattack as its cyber-physical nature allows for the dislocation of a human operator whilst an *observable, physical presence* in the form of the drone platform itself is maintained. There are clear similarities between drones and cyber attacks, as some have sought to highlight (Sanger 2017). Of most interest to our discussion are the parallels of anonymity that both can afford. As Mott notes, there is a "facelessness" to both the use of cyber and drones that presents ethical and attributional challenges (Mott 2018, 48). As discussed in Chapter 4, the anonymity surrounding drone use in some contexts is fostered by the traits of cyberspace that underpin it. We can begin to understand the drone as a physical manifestation of the attributional ambiguities found in cyberspace.

Where this physical manifestation of ambiguity becomes more interesting and more powerful, is in the latent disruptive potential surrounding the drone's presence that this cyber-physical coupling enables. Nowhere has this been better illuminated than during 36 hours at Gatwick Airport in December 2018. This incident holds significance in shaping understandings of the drone as an ambiguous device as it aptly demonstrates how incomplete information landscapes arising from multiple possibilities as to a drone's operator, purpose, or capability, give rise to an ambiguity in the drone's very presence that can itself become a vector of disruption. The Gatwick incident was described by officials as a "deliberate disruption" which grounded approximately one thousand flights and left many travelers stranded over a span of two and a half days (BBC News 2018a). Reported sightings of consumer drones led to the airspace surrounding the airport being shut down; the sheer presence of a CPS causing vast disruption. Ambiguity surrounded every aspect of the drone(s) during this incident: an ambiguous operator, ambiguous intent, ambiguous payload, and ambiguous potential effects if planes had been allowed to continue running. Arguably, it was not the drone itself causing the disruption, rather, the inherent ambiguity manifested in its *cyber-physical presence*. The presence of the drone(s) alone caused the physical emptying of the skies surrounding the airport. The movement of people and goods between geographical spaces was halted; an imposition of the drone's bodily absence onto the very people and objects dislocated from their intended destinations. Ambiguity surrounding the drone's presence and its possible consequences led to this piece of CNI grinding to a halt - an exploitation of ambiguity neatly encapsulated in consumer drone technology. This example is important because it highlights how the drone's remote physical presence plays an active role in its agency, beyond its capacity to surveil or strike. The cyber-physicality of the drone, co-opting facets of cyberattacks, creates ambiguity in the relationship between actor, tool and operational environment. Specifically, the dislocation of actor from tool and the opacity in their connection conjures multiple plausible interpretations as to operator identity and purpose.

The agency of drone presence is not only afforded from a known association to the operator or purpose for operation (as in the previous deterrent examples). It is fundamentally also tethered to the ambiguity - the inabilities to clearly delineate the operator or purpose. The remote nature of the physical presence of a drone leaves room for interpretation about who is operating it and for what reason, producing a powerful ambiguity that can cause disruption and chaos due to its hindering of effective responses.

6.3.2 The Dual Front: Cyber-Physical Attack Surface

As a CPS, drones are susceptible to both digital and physical attacks (Sanjab, Saad, and Başar 2020; Kong 2021a; Yağdereli, Gemci, and Aktaş 2015). As Chapter 5 explored, the modularity of drone technology allows it to be configured in variable ways and with various components – both digital and

physical, making them vulnerable to attacks against both types of components. Indeed, it has been noted that due to drones being fitted with various sensors, they can be exposed to numerous vulnerabilities (Rani et al. 2016, 331). Different components present different surfaces of attack depending on an attacker's objectives and on the security limitations of the components (Yaacoub et al. 2020).

As a CPS, the drone operates as part of a wider system, extending the attack surface further to off-board components. Insecure communication links between a drone and its GCS presents one such vulnerability that may be exploited (Rodday, Schmidt, and Pras 2016, 994). On-board system attacks can take the form of viruses, which can produce alterations in the drone's functionality including changing the rotor speed to make the drone crash (Kong 2021b). Other cyber-attacks against drones include de-authentication attacks, spoofing (Psiaki and Humphreys 2016b, 1258), denial of service attacks (Mairaj and Javaid 2022) the injection of malicious code to facilitate drone hijacking (Salamh et al. 2021, 3), the manipulation of captured drone footage to facilitate hijacking of the vehicle, and the injection of false sensory data to undermine the secure control of the device (Altawy and Youssef 2016, 10). As the scale of drone use widens with the development of the IoD (see section 6.2.1), further cyber challenges will arise. The far-reaching connectivity of the IoD concept introduces more points of vulnerability for cyber-attacks to be performed. Choudhary et al highlight the possibility for what they term "firmware replacement attacks" in the IoD environment. This type of attack entails a nefarious actor targeting the firmware upgrade process of IoD devices; replacing the valid firmware with a malicious variant (Choudhary et al. 2018, 8). It is noted that this is particularly a concern where software and firmware have been made publicly available by drone manufacturers, an increasingly common practice as discussed in Chapter 5.

Beyond attacks against drones, the drone itself can be used to carry out both cyber and physical attacks. Drones are well known for their military use as a delivery mechanism for lethal payloads (Gettinger 2019). So called 'kamikaze' drones further demonstrate the physical side of drone attacks; where the drone platform itself is the payload and detonates upon impact. The use of kamikaze drones in the ongoing Russia-Ukraine war and their devastating impact has sparked much discussion in recent times (Pettyjohn 2024; Plichta 2024; Hambling 2024). The use of drones to carry out *digital* attacks is much less prominent, but the capacity exists. An early instance where this capacity started to show its latent potential occurred in the 2014 Russian conflict with Ukraine. It is reported that separatists backed by Russia in the conflict used Orlan-10 drone systems in conjunction with an electronic warfare system known as the RB-341V Leer-3 to produce an aerial jamming mechanism (Digital Forensic Research Lab 2017). The drones were reportedly used to jam local communication towers and then acted as "cell site simulators" to enable psychological propaganda to be delivered to the phones of Ukrainian troops in the area. While not technically a cyber-attack, this use of drones

within an electronic and information warfare strategy demonstrates the duality of the drone's cyber-physical form and its potential to engage in and facilitate digital forms of attack. The use of drones to facilitate the simulation of signals can also be applied for defensive purposes. *HoneyDrone* is one example – this platform is designed to emulate protocols specific to drones. This allows it to become a flying cyber decoy, mimicking the identity of other drones nearby to divert an attacker's attention to the honeypot drone (Daubert et al. 2018).

Drones have been considered ideal for facilitating cyber-attacks due to their ability to reach inaccessible areas and their small size (Sethuraman, Vijayakumar, and Walczak 2020, 28). The use of drones for cyber related crime has garnered concern (Bressler and Bressler 2016). Modified consumer drones fitted with network intrusion software have been used to facilitate attacks including the theft of financial records, company information, and customer data (Claburn 2022). Furthermore, drones can be used to intercept private personal data such as usernames and passwords from mobile phones (Bressler and Bressler 2016, 3). For such uses, the physicality of the drone – specifically its modifiability (see Chapter 5), and its capacity to be aerially mobile – demonstrates its utility in facilitating cyber-attacks. This utility can be further observed in the use of drones for "stepping stone" cyber-attacks. This technique involves using a series of compromised 'hosts' to send attack commands *indirectly* to a target (He and Tong 2007, 1612). The idea being to make it harder for the origin point or identity of the attacker to be discovered. In a conventional cyber-attack of this nature, the hosts would be computers, however, the drone as a networked computing device can also be used as a host (Sethuraman, Vijayakumar, and Walczak 2020, 28). Host drones used in this way form a cyber-physical chain, where the attack request gets forwarded through that chain of drones until it reaches the drone in closest proximity to the target system. The drone's physical form as well as its digitality play a part in the attack. The drone's capacity to play a role in the breach of air gapped networks stands as another example of this emerging interplay between the drone's cyber and physical dimensions in the facilitation of digital attacks. Air gapping is a security control involving the segregation of computers in a network from unsecured external networks, intended to protect them from hacking (Aslaner 2022). A team of researchers demonstrated that a drone can be used to intercept information from a compromised air-gapped computer by capturing light pulses from the LED drive with sensors (Guri and Elovici 2018, 80). While the drone itself did not carry out the initial breach to install malware on the computer, its vital role rests in its physical capacity to hover outside a window in line of sight of the computer's hard-drive LED lights, capturing the encoded information with its sensor payloads. In this way, both the drone's digital capacity and its physicality play a role in assisting the breach and manoeuvre of the air gapping measure. The duality of such attacks adds new dimensions to our previous discussion of cyber-physical presence in 6.3.1. The drone's capacity to facilitate, enable, or extend the reach of cyber-attacks, represents a further extension of presence. Where in the previous section we talked of a transferral of presence (and thus agency) from operator

to drone, in acting as a host to facilitate cyber-attacks, the drone now acts as a conduit for that presence on its journey to a different destination: a computer network or system. Human presence is thus extended not only to the physical drone, but beyond it to the computer system or network it penetrates.

The capacity for drones to deliver or facilitate cyber-attacks further complicates issues of discerning a drone's purpose. It is not always clear what a drone is doing or what its purpose is. Ambiguities around whether a drone is carrying something and what is the nature of the payload, can be abundant. The capacity for drones to deliver cyber-attacks adds a cyber-physical dimension to this ambiguity. We now also must consider, is that payload physical or digital? Indeed, a drone tasked with delivering a cyber payload may look entirely benign (no visible payload). In this sense, its payload becomes another node of invisibility along with other digital invisibilities surrounding the drone explored in section 6.1.1. Thus, the number of plausible narratives as to what a drone's purpose or payload is multiplies further; the possibilities for its use are expanded through the drone's digital dimension. Moreover, the cyber dimension to the drone adds a further layer of uncertainty around its use. Thinking back to discussions of invisibility, a concern held by the public in relation to drones concerned inabilities to know whether data was being collected and how that data might be used (Department for Transport 2016, 5). When we consider the capacity for drones to be subject to cyber attacks in which collected data might be intercepted, the uncertainties surrounding possible uses for that data are compounded. Not only might we not know what data is being collected, by whom, and for what reason, we (as bystanders) are unable to know if that data is secure or vulnerable to interception by third parties. Duc Tran et al give a good hypothetical example in the context of drones used for police surveillance: "…police-operated UAS may frequently cross private properties on their way to an operational area. Under cyber-attack, the recorded video on the properties could be disclosed and then the privacy of those owners overflown could be violated."(Tran et al. 2022, 8). Aside from being a violation of privacy, such data in the hands of criminals could provide important locational and topographic information about personal property that could be used for nefarious purposes or sold on to other parties. Some have highlighted the legal ambiguities arising from the 'unique legal position' of drones being classed as both networked computing devices and aircraft:

> "From a malicious drone operator perspective, this inherently grants a high level of advantageous legal ambiguity and protection to criminals operating drones as counter-attacking efforts taken by victims may violate protective regulations or laws applicable to aircraft, but also anti-hacking laws meant to provide protections to personal computers, their data, and networks."(Kohnke 2022)

Finally, the additional distance that drones introduce between operator and effect in cyber-attacks contributes a further aspect to the complexities of attribution related to both drones and cyber-attacks. The degrees of distance presented in the use of drones for stepping-stone cyber-attacks aptly

demonstrates this. The indirect nature of such attacks introduces ambiguity as to the origin and attacker in question; potentially adding further complexity to digital traceability as discussed in section 6.1.1.

6.4 The Drone's Inheritance from Cyberspace

Cyberspace has been considered "tailor-made" for ambiguity (Libicki 2011, 4). Libicki highlights that even in situations where it is clear a system has been attacked, the attackers can remain "shrouded in mystery" (Libicki 2011, 4). Anonymity is enabled by dislocating an aggressor from the point of attack and the critical distance this creates. Distance is central to the appeal of cyber operations due to its facilitating role in distancing actor-from-action, and thus actor from culpability. Attributional challenges associated with cyber operations are widely acknowledged (Rid and Buchanan 2015; Tsagourias 2012; Crootof 2017, 582). Libicki further shows that when the broader context of a situation offers indicators of responsibility, cyberspace attribution can be problematic if actors conceal or deny involvement (Libicki 2020, 55). Examples of this can be seen in Russia's persistent denial of involvement in cyber operations during the 2008 Russia-Georgia war (Deibert, Rohozinski, and Crete-Nishihata 2012, 4), and in the use of cyber-proxies in Ukraine (T. Maurer and Geers 2015, 80–81). As this latter example demonstrates, actors can actively foster cyber-privateering to deliberately sow confusion and make attribution more difficult; thus amplifying ambiguity surrounding cyber attribution (Deibert, Rohozinski, and Crete-Nishihata 2012, 18). Cyberspace operations thus "unfold in a dense fog of ambiguity", holding significant implications for initiating an appropriate response (Libicki 2020, 55). Not knowing the perpetrator's identity can cast doubt on the practicality or desire for retaliation (Lindsay 2015, 57). Echoing this, Crootof (2017, 582) notes the near impossibility of immediate cyber attribution hindering timely responsive action. And herein lies the crux of the issue: ambiguity in attribution can disrupt abilities to respond swiftly and effectively. This is not an issue occurring solely in the context of cyber operations, increasingly we can observe attributional ambiguities occurring in relation to drones. This phenomenon is not a coincidence. It is a direct inheritance of the attributional ambiguities found in cyberspace by drone technology. Just as the geographical dislocation between a cyber-aggressor and their target makes immediate attribution more difficult, the distance created through the dislocation of the drone from its physical operator also renders attribution a challenge. However, as this chapter has revealed, the factors contributing to ambiguities related to attribution are multiple. Moreover, attributional ambiguities are not the only ambiguities the drone's digitality gives rise to. Findings throughout this chapter help illuminate a mapping of the drone's cyber-physical nexus and its relationship to the phenomenon of ambiguity as shown in Table 6.

Table 6. Mapping the Cyber-physical Nexus of the Drone to the Phenomenon of Ambiguity

Factor Contributing to Ambiguity	**Description**	**Resulting Ambiguity**
Traceability Challenges in Digital Forensics	Digital traceability challenges such as data integrity and verification issues expose how it is not always possible to have full confidence in digital evidence pertaining to drone use. The 'digital distance' created as data may be passed through multiple servers compounds issues of attribution.	Heightens ambiguity surrounding the identification of a drone's operator and the delineation of its activities, making it difficult to attribute specific actions to specific actors.
Algorithmic Opacities	The 'black box' nature of algorithmic processes used in drones for functions like data processing, and manoeuvrability and control can further obscure important aspects of the drone's activities or operation.	Holds the potential to contribute to ambiguities related to accurately attributing specific drone activities to specific actors.
Complexity of Expansive Drone Networks	The Internet of Drones and Ad-hoc Networks facilitate expansive and flexible operational coverage, but paradoxically introduce ambiguities at the operational level due to programming ambiguities and the opacity of algorithms used to facilitate such expansive networks.	Introduces ambiguity relating to traceability, reliability, and data transmission, complicating operational clarity and the ability to understand networked drone activities.
Transcendence of Virtual and Physical Boundaries	The drone's digital plasticity gives it the capacity to bypass digital defence mechanisms such as geofencing restrictions through techniques like GPS spoofing.	Amplifies ambiguity surrounding operator identity, location, or origin, as digital manipulation can misrepresent a drone's actual location or attribution.
Dual Materiality of Drones as Cyber-physical Systems	Drones operate as both a digital and physical entity which allows them to operate across both domains including as both an attack surface and vector in both physical and digital space.	Creates ambiguity relating to the drone's capabilities, purpose, or function due to it being unclear where the device sits on the spectrum between digital and physical attack capacities.

These associations and relationships illuminate the multiple interpretations and narratives that can arise surrounding the drone and its use which are influenced by ambiguities related to its purpose, capability, or operator. The drone's cyber foundation fosters various interpretations of these aspects, while at the same time its cyber-physicality further complicates the relationship between actor, tool, and operational environment. The dislocation of the actor from the device – in addition to the possible opacities outlined above – play a role in the generation of ambiguity. This dislocation is enabled by the cyber-physicality of the drone and it co-opts facets of cyberattacks. In a similar way to the dynamics of cyberspace and operations within it, distance regarding the drone (both physical and digital distance) complicates attribution and echoes the ambiguous complexities of cyberspace discussed by Libicki (Libicki 2011). It is within this context that we can begin to understand drones as

cyber-physical tools that inherit and amplify the ambiguities of cyberspace, expanding the phenomenon of ambiguity beyond the digital realm and into the physical world.

By focusing on the drone's cyber foundation we can better understand its role in both bridging and blurring the virtual and physical worlds. This is a device that increasingly embodies the intangibility of cyberspace, and this places us further at a distance from both its material reality and our capacity to fully understand its true capabilities and limitations. The cyber dimension of drones introduces a complex depth to this technology that we still do not fully understand. These findings help to re-orient our perspective to consider this complexity in more detail. In doing so it allows us to explore new conceptualisations of the cyber-physical drone and how it operates as both a tool and an extension of cyberspace in contemporary contexts.

6.4.1 Remote Physical Presence

The digital fabric of the drone allows it to act as an extension of the cyber domain in the physical world. This section argues that this cyber-physical nexus introduces a unique form of influence conceptualised in this work as *Remote Physical Presence*. Remote Physical Presence refers to the drone's capacity to exert influence beyond traditional physical and digital boundaries, blurring the lines between them. Understanding the drone as an extension of the cyber realm invites a reconsideration of the device's role and impact, challenging conventional understandings of presence and agency.

The blurring of the physical and digital in relation to drone technology has been considered by some scholars in relation to the use of drone technology in contemporary war. For example, Holmqvist's work on the bleeding together of the physical (corporeal) and the non-physical (incorporeal) is a crucial conceptualisation for evolving our understandings of drone use and other remote technologies in war (Holmqvist 2013). Thinking with the physical and non-physical materiality of the drone also paves the way for a better understanding of the tangible and intangible facets that comprise the cyber-physical system of the drone; illuminating other effects produced and enabled by the drone's place at the intersection of the virtual and physical realms, beyond the realms of surveillance and targeted killing. The phenomenon of ambiguity is one such effect, and it is tied closely to the drone's cyber-physicality. The idea of 'presence' is typically understood as a physical phenomenon, but the drone – as a physical extension of the cyber realm – challenges this. The presence of a drone is untethered to the physical proximity of the operator and is instead a physical entity that is mediated through digital means. This physical entity has a physical 'presence' itself within the spaces in which it operates. While this entity is, technically, tied to an operator – the influence of its presence is not always. For example, regardless of whether we can identify a drone operator, and thus deduce intent and purpose,

as we have seen in countless examples, the drone (absent information about operator, purpose, intent) still wields influence (e.g. shutting down airports). This remote physical presence is facilitated by the ambiguities inherent to the cyber-physicality of the drone. However, this is not where the influence of the drone's remote physical presence ends. As cyber-physical systems, the drone's digital connectivity allows it to traverse physical and virtual boundaries and roles; creating the possibility for persistent, continual influence that extends across both physical and digital domains. This mirrors broader trends of persistent engagement and enduring operational presence in cyber operations (Fischerkeller, Goldman, and Harknett 2022, 59–60). Being able to seamlessly transition between the physical and virtual, drones symbolise a new frontier of persistent influence that is underpinned by their inherent plasticity and cyber-physical nature.

We can understand the dynamic between ambiguity and the drone's cyber-physicality in two principal ways. First, the corporeal blurring of the tangible (the physical, material) and the intangible (the digital, immaterial) that drone technology represents produces a synchronous blurring between its physical and digital *possibilities*, and thus its potential capabilities. This chapter has illuminated ways in which the drone's cyber foundation complicates attribution and certainty surrounding what a drone is used for. The intangibility of where a drone sits on the cyber-physical attack nexus amplifies ambiguities pertaining to knowing with certainty what its capabilities and purpose are. Its existence on this spectrum renders its capacities at worst imperceptible and at best open to multiple plausible interpretations. Second, the inherent disconnect between the drone and its operator – made possible by the device's cyber foundation – creates a gap, inviting multiple interpretations regarding operator and purpose. It is within this context that we can understand the drone's remote physical presence as a property equipping the drone with a unique agency. Regardless of who is operating it and with what intent, and regardless of what the device might be carrying or collecting, the drone's sheer presence 'acts' at the threshold of the multiple interpretations it elicits. As explored through previous examples, this ambiguity can allow the drone to act as a vector of disruption simply by being present.

This agency is enabled and complicated by the drone's cyber-physicality, which allows it to embody characteristics from both the digital and physical realms and simultaneously blur the boundaries between them. This capacity to blur the boundaries can be understood as a form of "material vibrancy" (Bennett 2010). The drone actively extends the digital world into the physical world. We can begin to understand the physical drone as a vessel, containing the inherent ambiguous excesses of cyberspace and transporting them into the physical world. It carries with it the defining characteristics of cyberspace – including anonymity and attributional complexity – which the drone manifests in the physical world. In transferring these digital ambiguities into physical contexts, the drone challenges our conventional understandings of presence and agency, acting as a force that operates beyond human-centric frameworks and conjures complexities beyond initial intentions. It is here that we can

consider the idea of drone *excess*. In discussing the drone's capacity to "go beyond human intention" through means of it being repurposed for unintended uses, or its potential to be hacked and "go rogue", Grayson begins a very important strand of conversation pertaining to *drone excess*, agency, and how this emerging complexity could play a role in influencing and shaping things within the international arena (Grayson 2016b, 333–34). Similarly, we can understand drone ambiguity as an unintended excess emerging in relation to this technology and its use. The drone's inherent capacity to generate ambiguity regarding its purpose, operator, or capabilities represents such an excess that cannot be fully contained or predicted. In generating ambiguity, the drone goes beyond its initial intended uses, producing a phenomenon with the capacity to shape events, responses, and outcomes. This excess manifests in various ways – whether in attribution, capabilities, operator identities, or purposes – and can influence perceptions, interpretations, and consequences, creating unforeseen effects in both the civilian and military contexts.

6.5 Conclusion

This chapter has explored how the digital dimensions of the drone interact with the phenomenon of ambiguity. Through a discussion of digital invisibilities, unbounded digital frontiers, and the drone's unique position at the intersection of the cyber and physical domains, it exposes a plurality of ways in which the drone's cyber foundation contributes to the drone's inherent ambiguity. These digital ambiguities form a constellation around the drone spanning both extrinsic and intrinsic factors, adding to our understanding of the drone as an ambiguous device with the capacity to shape events, perceptions, and outcomes in the international arena.

Building on the anonymity identified as a key driver of drone-related ambiguity in Chapter 4, this chapter develops a more nuanced understanding of the mechanisms and technical factors underpinning it. While some have noted anonymity in relation to drones and ambiguity (Hwang 2021), the relationship between them and the factors giving rise to – or *enabling* – this anonymity has received little focus. Simply acknowledging anonymity or treating it as a given is insufficient. From where does such anonymity arise? What produces it, or what 'makes' it possible? In exploring this, the chapter contributes a useful dimension to the ongoing drone discourse, allowing for a more complete reading of the technology's utility in contexts where anonymity might be a challenge. Furthermore, the chapter reveals other ways in which the drone's intrinsic digitality contributes to ambiguity.

Section 6.1 demonstrated the array of 'invisibilities' associated with the drone's digital foundation. It discussed how the integrity of digital evidence from drones can be undermined by an array of factors. From digital traceability challenges influenced by external factors like drone customisation and

unreliable software tools, to the inherent susceptibility of drones to GPS spoofing, it exposed how compromised digital evidence diminishes confidence in data integrity and undermines trust in the attribution process. The opacity of AI and algorithmic processes further highlight ways through which the drone's digital foundation can give rise to ambiguities. The inability to fully comprehend how systems with higher levels of autonomy make decisions is complicated by their sheer speed of operation, outpacing human cognition and creating an information gap between input and output. The section further revealed the wider array of contributing external factors to algorithmic opacity, extending beyond the algorithm itself to other processes, structures, and practices beyond the digital.

Section 6.2 explored the notion of *digital boundlessness*, inviting us to reimagine our conceptualisations of physical and digital boundaries in the era of pervasive cyber-physical intermediaries like drones. Building on existing ideas of *boundless war*, this section explored how developments that are set to expand the scope and reach of drones (IoD and FANET) contribute to a sense of digital boundlessness. It considered how they might contribute to an amplified set of unknowns around the collection, transfer, and exchange of data between nodes across systems of extended connectivity and scale. Digital boundlessness was further explored in relation to the drone's capacity to circumvent digital boundaries such as geofencing. The drone's digital plasticity enables the physical entity of the drone to evade spatial limitations placed upon it. It is within this context that we can understand the drone as a tangible embodiment of digital plasticity through its functioning as an extension of the cyber domain in the physical realm.

The intertwined nature of the digital and physical dimensions of the drone were further explored in section 6.3. It was argued that it is within this complex interplay that the drone's capacity to 'act' resides – giving rise to a unique Remote Physical Presence with the capacity to influence events, decisions and outcomes. Using the example of the Gatwick drone incident, the agency of drone presence was traced to its cyber-physicality and its role in obscuring identity, intent, and purpose through the multiple narratives the cyber-physical materiality of the drone facilitates. The drone's capacity to facilitate, enable, or extend the reach of cyber-attacks, represents a further extension of presence. It contributes to the distance at play in the attributional challenges surrounding drones and adds another layer of complexity that can assist in masking an attacker. The capacity for drones to deliver or facilitate cyber-attacks further complicates issues of discerning a drone's purpose. In addition to ambiguities over whether a drone is carrying a physical payload or what it might be used for, the drone's digitality adds a cyber-physical aspect to this challenge. There now exists an additional possibility; that the drone's payload is a cyber payload which may be imperceptible, rendering the drone seemingly benign.

This chapter has explored the cyber-physical nexus of the drone and establishes a mapping of its

cyber-physical properties in relation to the phenomenon of ambiguity. It frames drones as possessing a unique Remote Physical Presence, a concept that captures the drone's unique capacity to 'act' by generating ambiguity not only in relation to its capabilities, purposes, and operators, but also through the drone's mere presence. In doing so, this chapter introduces a new way of thinking about drones – as an extension of the cyber domain. This repositions the drone as a physical entity that inherits the ambiguities characteristic of cyberspace and regenerates them in the physical world. This perspective opens up important avenues for exploration regarding the existing and emerging challenges of drones in modern security and conflict. Furthermore, it draws our attention to the ways in which their role as non-human actants can play a part in shaping and reshaping perceptions of presence and agency in both the physical and digital domains.

7. Assemblages of Ambiguity

The contemporary drone – a cyber-physical system operating across a spectrum of contexts and domains – epitomises the ambiguity inherent to the contemporary landscape of conflict and security. The drone exists at the threshold between different contexts, different states (forms, functions, digital, physical), different operators, and different applications. This poses challenges in relation to both their use, mitigation, and our understanding of this technology more broadly. Through an exploration of the drone's ubiquity, vast modification potential, and emerging utility at the nexus of the cyber and physical realms, the preceding chapters (4-6) provided insight into the ways in which the drone's intrinsic and extrinsic properties play an active role in the production of ambiguity surrounding the technology's use.

Each chapter elucidated key properties linked to drone technology that play an active role in the production of ambiguity around their use. First, Chapter 4 highlighted the ways in which this technology traverses domains, underpinned by its dual-use and multi-role nature, generating a plurality of legitimate and plausible narratives pertaining to use and purpose. This exploration gave rise to an understanding of the drone as a *liminal system*, a device with the capacity to exist at the intersections of, and transition between and across, a plethora of different contexts, uses, and narratives. Second, through a detailed exploration of the drone's vast extrinsic and intrinsic modification potential, both physical and digital, Chapter 5 illuminated the complex and multifaceted ways in which the drone can be modified. This exploration helped develop the concept of *drone plasticity*, encapsulating the device's capacity to not only be externally modified through both physical and digital means, but also its internal capacity to modify aspects of its own behaviour and even form. Finally, Chapter 6 sought to better understand the drone's cyber foundation, with the concept of *remote physical presence* explored in the context of the drone's capacity to act as an extension of cyberspace in the physical realm, seamlessly traversing the spectrum of the physical and virtual. Together, these analyses highlight that our thinking about drones needs to move beyond conventional categorisations, to a way of thinking that instead acknowledges their dynamic, non-static, and boundary defying qualities. How do we begin to synthesise these findings in a way that allows for a unified reconceptualisation of drones against the backdrop of its continual evolution of form, function and use.

This chapter brings together the prior analyses of drone ubiquity, plasticity, and cyber-physicality from chapters 4-6 to reconceptualise the contemporary drone as a *liminal assemblage*. It explores the key tenets that comprise the assemblage and further exposes its implications for how we understand the drone through the lens of Bennett's vital materialist concept of 'thing-power' (Bennett 2004). In

doing this, the chapter demonstrates how the drone's ubiquity, plasticity, and cyber-physicality can interact to produce a larger, ambiguous force or influence. The liminal assemblage conceptualisation offers a fresh way to approach the contemporary drone – a vastly modifiable, dual-use, cyber-physical system – and its capacity to exert effects beyond its initial purposes within the international arena. It argues for an understanding of drone technology as possessing a unique form of agency through its capacity to generate and compound ambiguity in contemporary conflict and security contexts.

7.1 Conceptualising the Drone as a Liminal Assemblage

The essence of the contemporary drone can be found in its vast applicability, modifiability, and ability to operate within and across a variety of contexts and domains. The drone's properties of ubiquity, plasticity, and cyber-physicality – as identified throughout this work – afford it the capacity to be multiple, to be *plural* in different ways. It is within this context that we can understand the drone as a liminal device, one that exists at the intersection between multiple things. To be liminal is to be positioned at a threshold, boundary, or to be "…intermediate between two states, situations…" (Oxford English Dictionary 2023c). The contemporary drone embodies an inherent plurality, enabling it to transition across various boundaries, including laws, ethics, and norms. The drone's very fabric fuses the nexus between the virtual and physical worlds, allowing it to serve as both a physical and digital attack vector and surface. Its dual-use nature blurs the lines between military and civilian uses, between conflict and security applications, and between conflict and competition in the international arena. Its versatility distorts clarity around legitimate and illegitimate usage, and its modifiability – both digital and physical – frustrates the knowability of its functions and capabilities. It is in this context of plurality, existence at the threshold and intersection of multiple possibilities, that this work understands the drone as a *liminal device*. It is precisely at these intersections – of being 'in-between' different possibilities – that multiple interpretations (ambiguity) surrounding drone use can arise and accumulate. These capacities to exist at the boundaries of different things are fundamentally driven by the drone's plasticity, cyber-physicality and ubiquity. While certainly, there are other socio-technical factors at play, including the cultural and political practices that coalesce around them, the role of intrinsic properties pertaining to the drone's physical and digital materiality cannot be overlooked or understated. Shedding light on these facets is important for gaining a more granular understanding of the device and its implications.

As the previous chapters have elucidated, plasticity, ubiquity, and cyber-physicality play a crucial part in the manifestation of ambiguity around drone use. Plasticity allows for the drone's vast modification potential, both physical and digital (enabling its existence at the threshold of differing functions, forms, capabilities). In turn, this allows for the vast array of applications the drone can be used for (existing at the threshold of different contexts, domains, uses). Underpinning this flexibility, is the

underlying cyber-physicality of the drone – without which, the drone would have neither such vast modification potential (both physical and digital), nor would it have the flexibility and reach that its digital foundation enables (enabling its existence at the threshold of the virtual and physical). Finally, ubiquity can be understood as an amplifier – in that through sheer numbers, it magnifies the possibilities around drone use (enabling its existence at the threshold of various uses, users, contexts, and capabilities). These constituent parts – plasticity, cyber-physicality, and ubiquity – each possess the capacity to produce ambiguity pertaining to different facets of the drone individually, but also coalesce, interact, and overlap in ways that further the phenomenon of ambiguity through the convergence of multiple thresholds. The next sections unpack this further.

7.1.1 The Machinic Assemblage of the Liminal Drone

Machinic assemblages are a useful way to conceptualise the configurations, entanglements and interactions between different components that coalesce to produce something larger than themselves. This Deleuzoguattarian concept views assemblages as 'machines' that come together to do something, or to produce certain things or effects (N. J. Fox and Alldred 2018, 194). In the same way, we can understand the ambiguous device that is the drone through the lens of the machinic assemblage. The drone's ubiquity, plasticity, and cyber-physicality can be understood as the constituent 'machines' that coalesce and play a part in the production of ambiguity in an overarching assemblage of liminality. This approach allows us to simplify a complex phenomenon such as ambiguity by unpacking it into constituent parts, allowing a view of how they interact, influence each other, or come together to produce the broader assemblage of ambiguity. Drawing on findings from across chapters 4-6, we can identify three distinct 'machines' contributing to the production of ambiguity surrounding drones. These will be referred to here as the plasticity, cyber-physicality, and ubiquity machines respectively:

- The Plasticity Machine

  The plasticity machine is fuelled by the drone's extrinsic and intrinsic modification potential. The device's vast capacity for both physical and digital alteration becomes a mechanism for the generation of multiple interpretations (ambiguity) pertaining to capability and purpose of use. The plasticity machine contributes to the material assembly of a plurality of functional narratives surrounding drones and their use.

- The Cyber-physicality Machine

The cyber-physical nexus underpinning the drone forms the central chamber of the cyber-physical machine. This nexus sees the corporeal blurring of the tangible, physical, material and the intangible, digital, immaterial. The cyber physical machine generates interpretive multiplicity pertaining to both contextual and functional narratives surrounding drone use.

- The Ubiquity Machine

The ubiquity machine has the drone's multiplicity of platforms and plurality of users at its core. The drone's vast proliferation, diverse user base, and the similarity of systems being utilised contribute to the material assembly of multiple narratives surrounding its context of use, purpose, operator, and legitimacy. The ubiquity machine generates an amplification of ambiguity through sheer numbers and variety multiplying the number of plausible possibilities around drone use.

The convergence of the ubiquity, plasticity, and cyber-physicality machines gives rise to an emergent liminality in the drone. To reiterate, liminality here refers to the drone's capacity to exist at the threshold between different contexts, different forms and functions, and different operators or uses. This liminality holds the capacity to generate multiple interpretations (ambiguity) and a plurality of competing narratives relating to the drone's purpose, operator, context of use, capabilities, and legitimacy. While each machine holds the capacity to generate ambiguity in different ways – as highlighted throughout chapters 4-6 – collectively, these machines interact and overlap to form an overarching assemblage of liminality (see Figure 8). This conceptualisation captures the interpretive multiplicity surrounding the drone, consequent of its capacity to exist – or perceptually exist – at the intersection or threshold of multiple things. This conceptualisation is important for our understanding of the contemporary drone, as it offers a way to begin unpacking in finer detail the components and aspects of the technology and its use that contribute to cognitive effects in both security and conflict settings such as plausible deniability, confusion, and inabilities to swiftly respond to incidents or events involving such tools. Indeed, thinking with the drone as a liminal assemblage assists in identifying ways in which interpretation and certainty pertaining to drone use can become complicated or frustrated due to the generation of ambiguity.

It is important to note that this work does not contend that ubiquity, plasticity, and cyber-physicality are the *only* factors at play related to the phenomenon of ambiguity around drone use. There are many human factors at play – from the cognitive functioning of brains perceiving drones and their corresponding interpretations, regulations, laws, and norms surrounding drone use, to media coverage of incidents and the role of language therein – to name but a few. There are also many socio-political

factors at play including things like the growing culture of digital adaptation in drones, the wider techno-politics of dual-use tools, and other cultural and political frameworks that drive and legitimise certain practices and developments. The conceptualisation put forward here foregrounds the non-human dimensions illuminated throughout the core chapters 4-6. This focus does not discount human factors or their importance, but rather seeks to provide a perspective that fills a crucial gap, where non-human aspects have been significantly overlooked in the nascent discourse around drones and ambiguity. This foregrounding has proved useful for not only exposing the active role of the drone's intrinsic material properties and components in relation to ambiguity, but also for revealing how some social factors at play can be located as emergent properties of those non-human materialities. For example, legal ambiguities identified in Chapter 4 – where ill-defined legal frameworks and lack of regulatory guidelines clearly lead to ambiguity in how states might respond to drones or actions carried out using them. These legal ambiguities can be understood as an *emergent property* of the complex interactions between the core ubiquity, plasticity, and cyber-physicality machines. Each of these machines, for instance, can produce ambiguity of a legal nature. Ubiquity – the widespread userbase and multiplicity of drone systems – generates legal ambiguities through amplifying challenges around regulation and attribution. Plasticity – the vast modification potential both physical and digital – contributes to legal ambiguities by producing a fluidity in drone technology that presents challenges for legal frameworks and definitions to classify and deal with. Similarly, the drone's cyber-physical nature may present legal ambiguities in terms of challenging distinctions between physical and digital actions, jurisdictions of responsibility, and accountability. Each can be understood as stemming from the three identified machines.

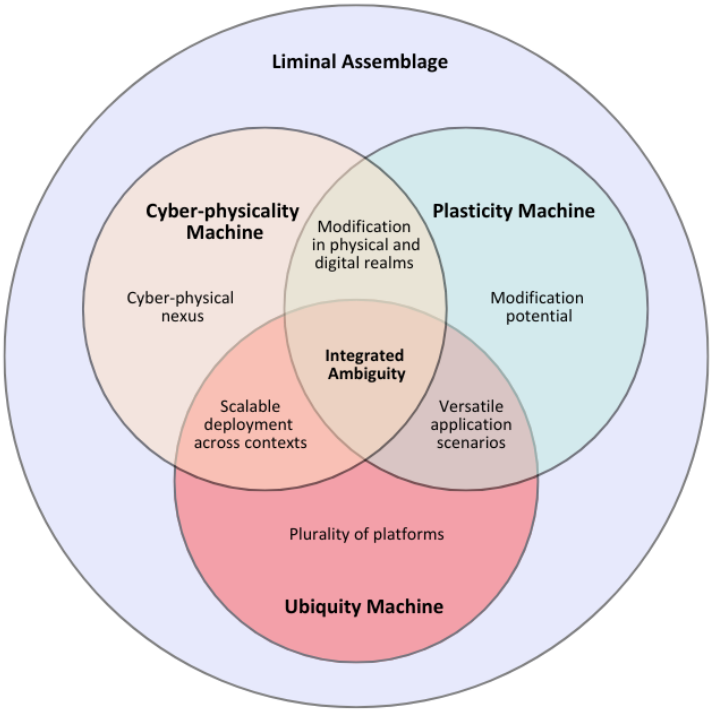

Figure 8. Euler diagram showing the interplay of each machine within the overarching assemblage.

7.2 The Drone and Liminal Agency

The conceptualisation of the drone as a liminal assemblage reveals its possession of a distinct set of properties that can elicit ambiguous interpretation. It is within this context that we can understand this device as one that possesses a novel form of agency through its capacity to generate ambiguity. The liminal assemblage has plurality at its heart. Each machine within the assemblage can give rise to a multiplicity of plausible narratives surrounding drone use, whether in relation to who is operating the device, in what context or for what purpose, or what the capability of the drone is. As these machines converge, this plurality wields influence. It can confuse, cause havoc, stymie responses, and facilitate deniability through the competing plausible narratives conjured. It is here, then, that we can talk about agency. This section draws inspiration from Jane Bennett's vital materialism, and specifically, her concept of "thing-power" to elucidate the implications of the liminal assemblage further (Bennett 2004).

For Bennett (2004), all matter – regardless of whether human or non-human – possesses a 'vitality' and agency that play an active role in shaping the world around us. Her concept of "thing-power" describes the way in which even inanimate objects display a unique capacity to act, influence, or create effects in the world, whether small or large (Bennett 2004, 351). This concept resonates with the findings of this research, which contends the drone possesses a distinct set of qualities facilitating the production of a certain effect or phenomenon – ambiguity. The concept of 'thing-power' can be applied to the drone to elucidate an understanding of its agentic capacities as a liminal assemblage. Bennett contends that 'things' always exist within an assemblage – a grouping of things – and that a 'thing's' power is derived from its interactions with that grouping (Bennett 2004, 354). Thinking with this idea in the context of the drone, the device's material existence is embedded within a liminal assemblage. This assemblage is the grouping of the drone's intrinsic plasticity and cyber-physicality, and its extrinsic ubiquity. To follow Bennett's notion of distributive agency, which contends the agentic capacity of assemblages is rooted in the liveliness of the materials that compose them, the drone's capacity to generate ambiguity can be understood as a function of this grouping (Bennett 2010, 21). Thus, the drone's ambiguous agentic capacity is not isolated, but rather occurs through the interactions within the liminal assemblage. While each component within the assemblage can give rise to ambiguity of some sort – its own 'vitality' – it is in the overlaps and interactions that we can consider the agency of the liminal assemblage. What follows explores these interactions.

7.2.1 Interactions within the Liminal Assemblage

To fully elucidate the drone's ambiguous agentic capacity, we must look at how the constituent machines interact to afford or enable the production of ambiguity. The following exposition of interactions demonstrates how the interconnected components within the overarching liminal assemblage each contribute to the amplification of ambiguity generated by the others.

Ubiquity and Plasticity

The growing ubiquity of drones presents an increasing range of contexts and environments within which drone technology is used. Their utility as an object with the capacity to fulfil a wide array or different roles and applications spurs their ongoing modification to new contexts and purposes. The dual-use nature of drones can obscure the lines between civilian and military applications, making clarity around determining purpose and intent a challenge. Operating across multiple contexts and environments, the drone's capacity for vast modification further obscures capabilities, functions, and intended uses.

Cyber-physicality and Ubiquity

The drone's cyber-physical nature presents inherent challenges around attribution which stem from its cyber foundation. The proliferation of drones amplifies ambiguity pertaining to attribution, as the number of possible operators and origins of the device increases. This is further compounded by the similarity of drone systems emerging in many contexts, and by the capacity for the cyber-physical nature of the drone to be exploited through cyber techniques such as spoofing to obscure location and operator data.

Plasticity and Cyber-physicality

The drone's cyber-physicality and plasticity are intimately entwined. The cyber-physical nature of drones facilitates vast modification potential – both physical and digital. Such modifications may be imperceptible, such as internal software updates that alter the capacities or capabilities of the drones behaviour in the physical world. These interactions compound ambiguities pertaining to ascertaining a drone's precise capabilities or functionality.

Ubiquity, plasticity, and cyber-physicality interact to produce a complex and multi-layered network of ambiguity. Bennett's concept of "thing-power" holds deep relevance for illuminating how drone

ambiguity manifests as a complex phenomenon within a broader assemblage that is larger than its individual parts. The cumulative compounding of ambiguity generated through interactions within the liminal assemblage presents challenges for the categorisation, interpretation, and thus response to, drone activities. Together, these interactions impart to the drone a significant 'thing-power' within the international arena, affording it the capacity to shape perceptions, responses, and events through complicating interpretation and certainty around various features of drones and their use. These interactions are summarised in Table 7.

Table 7. Summary of Machine Interactions within the Liminal Assemblage

Machine	**Interaction**	**Example**	**Resulting Ambiguity**
Ubiquity and Plasticity	Widespread accessibility, applicability, and presence across contexts facilitates an environment for modification to flourish. Plasticity allows the drone to adapt and transform to various contexts.	A drone produced for civilian use may be easily modified for military applications.	Ambiguity pertaining to purpose and function. For example difficulty distinguishing friendly vs hostile use.
Cyber-physicality and Ubiquity	Attributional challenges related to the drone's cyber foundation are compounded by drone proliferation and the similarity of systems.	Multiple parties operating similar or identical drone systems.	Ambiguity pertaining to attribution, accountability, and purpose.
Plasticity and Cyber-physicality	The cyber-physicality of drones facilitates the vast physical and digital modification of the device, including modifications not easily visible such as software alterations affecting physical behaviour.	Drone software can be altered to allow it to switch between remote and autonomous functionality.	Ambiguity pertaining to function, capability, and operational state.

Ultimately, this conceptualisation illuminates an understanding of the drone as a device possessing a unique 'thing-power', afforded by its material properties of ubiquity, plasticity, and cyber-physicality, and playing an active role in the production of ambiguity around drone use. This approach aligns with Bennett's arguments in relation to the role of inactive or non-human actors in shaping and influencing outcomes within complex systems (Bennett 2004; 2010). Further, it demonstrates how the resulting ambiguities are intrinsically linked to the material composition of drones and not merely by-products of the environments within which they are used. In exposing how these material compositions – encapsulated within the ubiquity, plasticity, and cyber-physicality machines - collectively exert ambiguous influence, their dynamic role in shaping how drones are perceived and engaged with across various contexts is highlighted. This conceptualisation thus argues for an understanding of the drone as an active agent in the generation of ambiguity. This understanding holds implications for how we think about the contemporary drone and its role in both security and conflict. It raises critical

questions about the exploitation of ambiguity through disruptive technology, highlighting the potential for cyber-physical technologies like drones to facilitate political violence through the purposeful leveraging of ambiguities inherent to the technology.

7.3 The Machinic Mediation of Ambiguity

The drone is a device whose pluralities give rise to ambiguity. As other scholars have noted, drones are emerging as useful tools in subthreshold environments (Hwang 2021; Mumford 2020). As outlined in more detail in Chapter 1, subthreshold and 'grey zone' contexts have been described as characterised by ambiguity (Votel et al. 2016a, 102; Hoffman 2016a; Nathan et al. 2016, 18). While the application of drone technology within these contexts is not surprising, the mechanisms behind their increasing utility have been overlooked and underexplored (see Chapter 2, section 2.1). Establishing an understanding of the drone's efficacy in such contexts is a crucial step to informing better approaches to mitigate their impacts. The conceptualisation of the drone as a liminal assemblage provides valuable insights into the mechanisms of ambiguity facilitated by the drone. It illuminates the multifaceted ways the drone's material properties can both create ambiguity and be used to exploit ambiguity; contributing to our understanding of their utility in subthreshold environments.

The liminal assemblage presents ample opportunity for multiple narratives surrounding drone use to emerge. This multiplicity plays a part in the facilitation of plausible deniability, strategic confusion, and cognitive impasse. While we can understand this multiplicity of narratives as an emergent excess – an unexpected by-product of the contemporary drone, its properties, and use – we are already seeing aspects of the drone's ambiguous potential being leveraged intentionally. This is particularly the case in relation to the evasion of culpability; something that Hwang has aptly observed in relation to how non-state actors can "feign innocence" with drones (Hwang 2021, 336–39). What the conceptualisation of the liminal assemblage allows us to do, is understand *how* this is working. Feigning innocence in relation to drone use is a purposeful exploitation of the multiple, competing narratives the drone can conjure. This plurality of competing narratives is produced through the interactions of ubiquity, plasticity, and cyber-physicality within the liminal assemblage of the drone. This conceptualisation allows us to see the ways in which actors using drones in different contexts can – knowingly or not – leverage different interactions within the liminal assemblage to benefit from resulting ambiguities pertaining to operator identity, origin, function, purpose or capability around drone use. The following vignettes offer brief illustrative examples to highlight how the liminal assemblage allows us to understand the complex interplay of factors at play in relation to ambiguity that existing and traditional analyses overlook. It is important to note that these examples span different contexts, not only the context of conflict. This is to highlight that we can observe the

phenomenon of ambiguity pertaining to drone use occurring in a range of contexts, from the terrorist use of drones by violent non-state actors, the use of drones by state actors outside the confines of conflict, to disruptive use of drones in domestic security situations.

Daesh use of Modified Quadcopters in Syria, 2017

The early use of modified consumer drones by Daesh in Iraq and Syria during 2017 presents an interesting example to illustrate how the liminal assemblage conceptualisation can enhance our understanding of drone use and the associated ambiguities it generates. The group began repurposing and weaponising consumer quadcopters in 2016, with their use expanding significantly in early 2017 presenting considerable challenges to U.S. backed forces in the region (Waters 2017). Multiple parties to the conflict were utilising consumer quadcopters for surveillance and other non-hostile purposes, thereby creating a ubiquity of similar devices of varying use being in operation and providing ample conditions for ambiguity regarding ownership and intent to manifest. It is reported that Daesh purposefully began deploying their modified, weaponised devices at times that coincided with the Syrian Democratic Force's (SDF) own deployments of surveillance drones (Gibbons-Neff 2017). The plurality of similar devices allowed for Daesh to fool ground troops into thinking friendly, unarmed drones were overhead; leaving them exposed to harm. The lens of the liminal assemblage allows us to see how the interaction between the ubiquity machine (plurality and similarity of platforms) and plasticity machine (plurality of capabilities due to vast modification potential) was leveraged to create strategic confusion. The multiplicity of systems in the airspace, coupled with inabilities to distinguish hostile armed drones from friendly unarmed drones caused confusion and havoc on the ground. The capacity for Daesh to manipulate ground troop perceptions around intent and purpose of the drones was afforded through the plural narratives enabled by the plasticity and ubiquity machines. In this case, the lens of the liminal assemblage assists in elucidating the mechanisms through which ambiguity was successfully produced, and further exposes the strategic exploitation of these ambiguities.

The Gatwick Drone Incident, 2018

The Gatwick Drone incident of 2018 presents a fascinating example to illustrate the agentic capacity of the liminal assemblage surrounding drone technology. Reported drone sightings at Gatwick Airport saw this piece of critical national infrastructure grind to a 36-hour halt (BBC News 2018a). The level of disruption and chaos caused, along with the economic damage caused from thousands of flight cancellations sparked a sizable investigation by Sussex Police to identify those responsible (BBC News 2019a). It further ignited mass speculation in the media over who was flying the drone and for what purpose, with conflicting reports and inconsistent narratives complicating speculation (Shackle 2020b). At the time of writing, there remains no evidence or verification of a drone's actual presence at the airport, leading some independent investigators and aviation experts to conclude there is a high

likelihood that no drone was involved at all (Airprox Reality Check 2024). However, whether the drone was present or not, this incident was shrouded in ambiguity. The liminal assemblage around the drone played an active role in the generation and perpetuation of that ambiguity – even if only related to *the idea* of a drone being present.

Assuming for a moment that a drone *was* present, interactions between the cyber-physicality, ubiquity, and plasticity of the drone can be seen to play a part in this disruptive event. Anonymity inherited by the drone from the cyber domain allowed the operators to cause mass physical and tangible disruption while obscuring their identity and maintaining this ambiguity for over six years. The ensuing chaos is further linked to the ubiquity surrounding drones – a device whose vast accessibility and user base facilitates multiple plausible possibilities as to its owner and context of use. The drone's inherent plasticity further contributed to ambiguity here, with its vast capacity to be modified eliciting multiple plausible possibilities as to its capability, function and potential for hostile use. Multiple plausible narratives elicited through the cyber-physicality, ubiquity, and plasticity of the drone produced layers of ambiguity around why that drone was present, what its purpose was, who was flying it, and what risks its physical presence might pose. This compounded ambiguity had ripple effects not only throughout the incident, but also in the response on the ground and the media coverage surrounding it.

Perhaps most interesting about this incident, is that regardless of whether there was a drone there or not, ambiguity surrounded every aspect of the *very notion* of a drone's presence. Fundamentally, these ambiguities are driven by the liminality of the device – its existence at the boundaries of multiple uses, capabilities, and contexts. While we must be cognizant of other factors also contributing to ambiguity (conflicting eye-witness reports is one example), we can observe the drone's overarching liminality contributing heavily to the complication of interpretation and certainty we saw unfold around this event. In so doing, the event underscores the latent agency the liminal assemblage around the drone possesses. From the physical disruption caused to travellers and airspace, the psychological impacts of a potential drone presence causing panic, to unpreparedness for such an event sparking uncoordinated and insufficient responses (College of Policing 2019). At Gatwick, the drone 'acted' – merely through the very *idea* of its presence.

Abqaiq-Khurais Oil Field Attack, 2019

A drone attack on the Abqaiq-Khurais oil field in Saudi Arabia in 2019 demonstrates an instance where we can observe plausible deniability surrounding the use of drones, actively facilitated by the interaction between the ubiquity and cyber-physicality of drones. The incident involved a coordinated drone and missile strike on two major oil installations in Saudi Arabia causing a significant disruption

to global oil supplies (Hubbard, Karasz, and Reed 2019). Following the attack, the international community laid blame with Iran, who denied any involvement (BBC News 2019b). The strike was swiftly claimed by the Houthi rebels, a militia group based in Yemen and closely aligned with Iran (Altaher 2019). Components found in some Houthi drones are indistinguishable from those found in Iranian-made systems, and drones often claimed by the Houthis as indigenous are often manufactured and supplied by Iran (Conflict Armament Research 2020, 19). This plurality and similarity of systems adds complexity to the task of determining attribution, which can already be complex due to the cyber foundations of the drone providing levels of anonymity. The international community was left with doubts following the Houthi claim of responsibility, largely against the backdrop of a general suspicion of Iranian orchestration given the state's long-standing rivalry and tensions with Saudi Arabia (Kirkpatrick et al. 2019). Yet, the initial plausibility surrounding the potential for the Houthis being to blame slowed responses. Saudi Arabia had to wait for outcomes of UN investigations on the site and drone debris before being able to consider a response. Initially, the UN were not able to attribute the drone strikes to Iran, nor confirm their involvement (BBC News 2019e). Further investigation of drone parts and damage at the site ultimately revealed the likelihood of the drones being launched from a northern position, consistent with the trajectory of an Iranian launch site (Pamuk 2019). This example is interesting as it highlights the interaction between plurality surrounding drone narratives and plausible deniability. Although short-lived, deniability was enabled and maintained in this case by the existence of plural plausible narratives driven by interactions between the ubiquity and cyber-physicality of the drone. One of the most interesting and concerning aspects of this attack was in the way the drones and missiles used seem to have been selected specifically due to certain technical elements of their design making them more deniable. Following the attacks, it was proposed that the dynamic manoeuvrability inherent to the design of the weapons themselves had allowed them to approach the target from directions favourable for kinetic effects, survivability and *deniability*. Moreover, it was suggested the design of the systems was purposefully made distinct from those within Iran's own arsenal; a purposeful construction of what was described at the time as an "elaborate deniability mechanism" (Rogoway 2019). The liminal assemblage assists in elucidating how plausible deniability was constructed in this instance, with the attempt to obfuscate the origin of attack underpinned by the cyber-physical nature of the drone, compounded by the drone's manoeuvrability and modification (plasticity), and further strengthened by the drone's ubiquity in terms of the similarity of systems between Iran and its proxies.

Kremlin Drone Incident, 2023

Drones have become a staple weapon in the ongoing Russia-Ukraine war. While in many cases of drone use in this context intent, purpose, and operator are often apparent, we can still observe the exploitation of ambiguity pertaining to their use in some instances. The targeting of the Kremlin in

Russia by explosive drones in 2023 stands as one such example. Two drones were reportedly disabled on their approach to the Kremlin in what Russia called an "assassination attempt" against Vladimir Putin, claiming it was orchestrated by Ukraine (Vernon 2023). The event sparked much speculation over the origins of the attack, with some analysts suggesting a false-flag operation coordinated by Russia (Trevelyan 2023). Ukraine denied involvement in the attack, as did the U.S, who Russia accused of having some level of involvement (Picheta, Chernova, and Goodwin 2023). Lack of concrete evidence left the international community with many questions over the true origins and intent behind this attack. This example demonstrates the interaction between the cyber-physicality and ubiquity of the drone. The widespread availability of drones to all parties involved, and the ability to operate them over great distances due to their cyber-physicality lays the foundations for multiple plausible interpretations over operator identity and origin of the attack. The lens of the liminal assemblage helps demonstrate the drone's existence at the intersection of multiple interpretations and plausible narratives, which are actively generated by the interaction of the constituent parts within the assemblage. Moreover, it sheds light on how ambiguity can be leveraged and exploited by powerful actors – for example, to justify retaliation, evade blame, or to manipulate the perceptions of the public or wider international community.

Whether eliciting multiple interpretations pertaining to operator identity, device origin, purpose, capability, or even presence, these examples help to illustrate the drone's capacity to 'act' on perception, interpretation, and on certainty. Through its ubiquity, plasticity, and cyber-physicality, the drone conjures multiple interpretations that produce ambiguity. In turn, this ambiguity can stymie responses, confuse decision-making, and generate cognitive impasse. This agentic capacity can shape perceptions and interpretations as well as lead to real tangible effects and the shaping of actions both in the domestic security context and in the wider international arena. Thinking with the liminal assemblage and its constituent 'machines' allows for a more nuanced understanding of how ambiguity can be constructed into drone use in different ways and to achieve different things. This helps to unpack facets of how drone strategies might be put together in different scenarios and contexts by those using them. Rather than treating ambiguity as a by-product or a given condition – we can begin to trace its building blocks, ascertaining how drawing on different narratives can be used to produce different types of cognitive effect such as confusion or deniability. This can assist in developing more informed approaches to countering and mitigating such effects, which in turn can enhance the capacity to respond to incidents and events. This holds importance for being able to better understand why certain actors are adopting this technology in particular ways in different contexts.

7.4 Machinations of Ambiguity

Understanding the drone as a liminal assemblage contributes to a critical understanding of the ways in which drone technology can be exploited both strategically and politically by different actors across various contexts. It exposes how ambiguity – facilitated by properties inherent to the device – is emerging as a tool that can be leveraged to the advantage of actors, serving specific agendas, including the facilitation of aggressive actions and political violence with reduced risk of retaliation. From deliberately obscuring intentions, concealing identities, and the evasion of culpability, to generating strategic confusion – the drone provides fertile ground for deceptive tactics and manipulative practices to flourish. These practices are problematic, not only due to their capacity to amplify ambiguity, but because they serve as mechanisms through which actors can manipulate situations to their advantage, reinforce power structures, and control narratives to best serve their aims – often at the expense of transparency and truth. Indeed, they contribute to broader issues pertaining to transparency, accountability, and the facilitation of political violence. The liminal assemblage conceptualisation exposes the ways in which the drone's material properties equip it with a 'thing-power' that extends beyond its mere utility, and actively plays a role in shaping events and the political landscape through facilitating deceptive practices.

Ambiguity by Design

As drone use continues to increase, and as innovations in drone design and production unfold at a pace hard to keep up with, thinking with the liminal assemblage raises important questions for the future of drone use. As the exploitation of ambiguity in relation to drone use becomes more prevalent, we must be cognizant of the potential for liminal features to be embedded in the design and deployment of drones in future. A second phase of ambiguity – beyond the ambiguities identified in this work – may emerge – where drones designed intentionally to deceive and confuse become a distinct possibility. This raises the concerning notion that drone designs begin to purposefully incorporate properties to increase the ambiguity surrounding the system, thus increasing their deniability. Where to date the ambiguity of the drone has been utilised and exploited somewhat subconsciously, or as a useful by-product of the nature of the device, what may ultimately emerge is a distinct and troubling trend in the purposeful creation of ambiguity in such devices. We are already standing at a moment in time where the emergence of other disruptive technologies such as additive manufacturing (3D printing) are poised to revolutionise aspects of drone production (See Chapter 5). This may pose challenges that will likely frustrate existing ambiguities that can arise in relation to attribution around drones as third-party components and home-made 3D parts are harder to trace. As this, and other innovations and evolutions in both the design and production of drone devices unfold, the liminal assemblage concept becomes even more crucial. The exploitation of ambiguity – both

accidental and intentional – can be understood and traced through the lens of the liminal assemblage and the interactions within it. However, it is not a static concept. The drone is continuously evolving, incorporating new dimensions. The conceptualisation of the liminal assemblage provides a way to categorise the material properties of drones holding relevance for understanding ambiguity – offering a way to explore their implications.

Drone Futures

As the drone continues to evolve, the core concepts of ubiquity, cyber-physicality, and plasticity offer a foundational and adaptable basis for incorporating new dimensions of this, and other technologies for exploring their implications. Chapter 5 provided an initial exploration of some of the ways in which the drone is poised to evolve, yet the future holds the potential for drones to evolve in ways we are yet to imagine. What happens when drones begin to take forms we are yet to consider, or when advanced polymorphic drones with the capacity to seamlessly shift between different domains, forms and physical states become established? Moreover, developments in domestic and practical humanoid robots such as Tesla's 'Optimus' (TESLA 2024), and Boston Dynamic's 'Atlas' (Boston Dynamics 2024) point to a future where cyber-physical systems like drones and robots do not simply serve as tools but may become more incorporated as active participants in society that shape our environments. Such cyber-physical, modifiable, and reproducible systems raise questions about how they might redefine the environments they inhabit and our perceptions and interpretations of their roles and presence therein. This work, while using the drone as an exemplar, does not treat it as an isolated object, but as part of a dynamic system of qualities. It thus provides an important framework that can be applied going forward regardless of the ways in which the forms, functions, and uses of future drones, robots – and other cyber-physical systems – come together in divergent ways.

8 Conclusion

This concluding chapter offers an evaluation of the approach taken in this research and a detailed overview of the research's core findings, contributions, and implications for theory and practice. The evaluation is presented first (8.1), evaluating the efficacy of the research design, approach to data collection, and method of analysis. It then turns to consider the efficacy of the integration of Thematic Analysis informed by New Materialism, highlighting its value for exploring complex socio-technical problems within International Relations and Security Studies. This approach facilitated a novel exploration of the drone's relationship with ambiguity, moving from external manifestations of ambiguity around drone use, to internal ambiguities stemming from the technology's intrinsic and inherent properties. The multidimensional insights that emerged from this approach demonstrate new approaches to the application of new materialism which offer fresh perspectives on complex socio-technical challenges in international relations and security studies. The evaluation further outlines challenges that occurred throughout the research, detailing how these were overcome, and directions for future studies undertaking a similar approach.

The concluding section (8.2) discusses the key findings and contributions of the research for Security Studies and explores their implications for theory and practice. This work advances our understanding of the complex socio-technical device that is the drone through a material-oriented enquiry into the drone's relationship with the phenomenon of ambiguity. It furthers the material discourse on drone technology by exposing how extrinsic and intrinsic properties of the device – such as ubiquity, plasticity, and cyber-physicality – play an *active role* in the production of ambiguity around drone use. In doing so, the work enriches the dialogue on the socio-technical and socio-political impacts of drones, while providing new ways to conceptualise and analyse how the plurality of narratives surrounding drone use can shape events, perceptions, responses, and outcomes in the international arena. It introduces three novel conceptual developments that expand our understanding of drone technology and its implications for international security: the *Liminal Assemblage* – which illuminates how drones blur and traverse numerous boundaries and categorisations to produce ambiguity; *Drone Plasticity* – which captures the continuous, indelible and permanent alteration of drones due to their vast extrinsic and intrinsic modification potential, which complicates our understanding of it capability and purpose; and Remote Physical Presence – which reframes the drone as a cyber-physical entity that inherits and amplifies the ambiguities of the cyber domain into the physical world, exerting influence across both realms. Together, these concepts reveal how ambiguity pertaining to drone use is not simply a by-product of human strategy or operational context, but is actively produced and perpetuated through the material and relational properties of the drone itself. In foregrounding the material and technical aspects of drone technology, which have often been underexplored in comparison to the social, ethical, and legal implications of drones, the research provides an important

new understanding of the material agency of the device. It exposes how the drone's inherent properties interact with and shape human perceptions, influencing how drones are understood, utilised, and reacted to in various contexts. Consequently, it provides an important understanding of how drone technology can be leveraged to generate ambiguity, providing a fundamental benchmark for reconceptualising the influence of complex remote-physical technologies in the international arena going forward.

8.1 Evaluation of Research Design and Method

An important component of methodological rigour is reflecting on the research process and evaluating its efficacy. The research design for this work integrated the use of Reflexive Thematic Analysis with New Materialism to explore the phenomenon of ambiguity related to drone use. This approach was chosen to leverage the strengths of both new materialism – with its emphasis on material factors and non-human agency – and thematic analysis, a rigorous and structured approach excelling at identifying patterns across data. The nature of the multifaceted problem-space at the heart of this research made this integrated approach particularly suitable. This section highlights key strengths, weaknesses, and challenges identified in this research design throughout its progression, followed by considerations and improvements for future work taking a similar approach.

Primary strengths are identified in the integration of thematic analysis and new materialist thinking, which informed aspects of the approach. This union provided an effective combination for the in-depth exploration of the specific problem-space in this work. Primary challenges included limitations relating to manual systematic database searches, and temporal factors relating to the use of closed datasets for thematic analysis to explore an emerging phenomenon situated in the fast-paced and changing landscape of drone use. This sections first outlines the efficacy of the overarching research design. It then considers the utilisation of reflexive thematic analysis informed by a new materialist theoretical framework, reflecting on both the utility of the integrated approach, and the value of this approach for studying the problem-space. It offers an evaluation of what worked well with the research design and outlines any challenges that arose throughout its conduct. Finally, it reflects on what the application of this approach reveals for the use of new materialism both in relation to the study of the drone, but also its utility for approaching complex problems that sit at the intersection of multiple disciplinary boundaries. Principally, the research demonstrates how the integration of TA and new materialism can reveal socio-technical dynamics that are often overlooked, offering unique insights into complex socio-technical systems like drones and their implications and effects in the international arena.

8.1.1 Data Collection Process

Data collection for this research relied on secondary sources due to the circumstances of Covid-19 affecting initial plans for primary data collection (see section 3.6 of Methodology which outlines these limitations). The collection and utilisation of secondary sources held both advantages and disadvantages for the study. The flexibility in using secondary sources was a key advantage, offering a wide scope in the variety and diversity of sources that could be obtained for inclusion in the thematic analysis. This helped to ensure that a variety of voices, perspectives, and origins of information pertaining to the research aims could be utilised and considered, facilitating depth and analytical richness. A central challenge tied to the use of secondary sources, however, arose in relation to the systematic approach taken to collecting this data. The manual use of search strings presented occasional challenges. For instance, during data collection for Chapter 5, which examined drone technology's modification potential and its bearing on ambiguity, the original search strings did not capture all relevant materials. This became clear during the coding process, where alternative terms emerged. A specific example was the use of 'morphing' drones which did not capture materials using an alternative term 'aerial manipulation', common in some disciplines. The impact of this on the findings was minimal as the term was identified during coding and accounted for within the analysis. However, it highlighted the limitation of anticipating all possible search terms within this kind of search strategy. While this is the case, following a structured search method is still beneficial. In future work, this can be mitigated by augmenting the data collection process using software to automate elements of the search process.

8.1.2 Application of Thematic Analysis

The choice of utilising Reflexive TA was driven primarily by its flexibility, proficiency in identifying patterns within data, and the methodological clarity and rigour that has been established surrounding this process (Braun and Clarke 2012; 2021). Its suitability for this research was further compounded in its capacity to facilitate the theoretical stance and subjectivity of interpretation, which was informed by new materialist thinking and concepts. Following the TA process as outlined by Braun and Clarke provided a structured way to approach and synthesise the collected data, facilitating the identification of patterns across a broad range of data (Braun and Clarke 2021). Importantly, it provided the level of flexibility necessary in an integrated approach, where theoretical insights drawn from new materialism informed aspects of the interpretation and analysis. The reflexive nature of this method ensured the influence of these theoretical positions is accounted for and reflected upon throughout the process.

Throughout this research, three separate thematic analyses were carried out to gain deep insight into three interconnected areas pertaining to the research aims. This approach was slightly unusual, but

allowed for a rich depth of exploration, providing comprehensive analysis into each component. This structure facilitated a unique dimension to the research, allowing for the structured exploration of the phenomenon of ambiguity from the external (how ambiguity manifests around drone use) to the internal (the physical and digital components that play a role in the manifestation of ambiguity around drones and their use). This unique external-internal dimension was facilitated by the three-phase approach, allowing for findings from one TA to inform the conduct of the next. This approach enabled a more targeted approach to elucidating the overarching research aims.

One challenge found in the application of TA in this work was in conjunction with the type of data utilised. The variety of sources being utilised in lieu of primary data collection via interviews meant that datasets were comprised of a range of different materials. These naturally varied in length, from reports of over a hundred pages, to single page articles or materials. This introduced challenges around the process of coding, where careful balance in the depth of coding across these materials was necessary to avoid bias in relation to longer and more detailed documents. To mitigate this, an iterative process was taken in relation to coding, involving initial broad coding across all documents to ensure main patterns and themes relevant to the research questions were identified. This was then followed by a second, more detailed coding. The iterative review and refinement of codes further ensured documents contributed equally to the identification of themes, regardless of their differing lengths.

The utilisation of qualitative software tool NVivo through the TA process was useful and proved integral to the organisation and tracking of codes and themes. While some technical issues made learning and using NVivo a lengthy process, the overall benefit to the work of leveraging this tool to help keep the coding process organised was significant.

8.1.3 Integration of Thematic Analysis and New Materialism

The approach set out to leverage conceptual insights from new materialism in the interpretation of patterns and themes from the data involved. In practice, this approach worked well overall, allowing for codes and themes to be interpreted through the lens of new materialism. The integration of TA with new materialism provided a useful lens to approach the research questions, allowing for the establishment of a foundational understanding of the components and facets at play between drone technology, the phenomenon of ambiguity, and related situational dynamics.

The process of interpretation and engagement with new materialism unfolded naturally in the TA process. Rather than new materialist concepts guiding the initial coding process, coding was conducted inductively – allowing for broad capture of material relevant to the research questions.

Coded data was then reviewed for relevant themes, informed by new materialist concepts, and later discussed in relation to new materialism more directly. While this approach effectively highlighted material considerations, dynamics, and affordances in relation to the drone's materiality and the phenomenon of ambiguity, the process may have benefitted from a more structured application of new materialist concepts to further ensure consistency in the integration of theoretical concepts.

The integration of new materialism with thematic analysis provided a useful lens through which to approach the research question, enhancing our understanding of how drone technology interacts with the phenomenon of ambiguity. This approach allowed for the importance of physical and technical components of the technology to be taken into direct consideration. Findings of the TA were informed by new materialism to expose the agential capacities of these components, and an exploration of how they impact the dynamics of situations and environments. The research adopted a vital materialism in its interpretation of findings, drawing on Jane Bennett's concept of vibrant matter (Bennett 2004). The utility of this conceptual lens was found in its efficacy for gaining better understanding of how the drone's intrinsic properties play an active role in the production of ambiguity. Seeing the drone as actively shaping perceptions, actions, and events, with an intrinsic 'power' to create novel modes of influence and effect. The research exposed how the material modification potential of drone technology – both digital and physical – plays an active role in the production of ambiguity surrounding their use. Moreover, it facilitated the identification of other facets playing a role in the socio-technical materiality of the phenomenon of ambiguity. For example, in exposing aspects of the digital modification potential of drones, it further highlighted the role of other actors and actants in this process that must be taken into consideration, such as drone enthusiasts utilising software customisation kits, and the companies creating such kits. While beyond the scope of the project to delve into each area highlighted within the overarching assemblage of socio-technical factors involved, the approach demonstrates efficacy at highlighting multiple facets playing a role in certain phenomena which can be a springboard into future research topics. The integration of TA with NM provides an effective mechanism for the broad capture of themes pertaining to material-oriented enquiry, facilitating a comprehensive exploration of dynamics, agentic capacities and relationships. The approach effectively captured the complex interactions and relational dynamics between drone technology, its constituent parts, the phenomenon of ambiguity, and the environments within which they operate. It offers nuanced insights into how drone implementation and design can be exploited by subthreshold actors for intentional ambiguity, enriching the dialogue on drones in Critical Security Studies by offering deeper material-oriented insights into the agential capacities of complex socio-technical systems such as the drone and their implications for contemporary security and conflict.

8.1.4 Implications for New Materialism

The integration of TA and New Materialism through this work facilitated significant contributions to furthering our understanding of the complex socio-technical system that is the drone. The approach enabled an exploration of themes around the phenomenon of ambiguity pertaining to the drone, in conjunction with a material-oriented exploration of the relational dynamics, affordances, and capacities of the drone's materiality (both physical and digital) in relation to that ambiguity. In doing so, the work exposes the ways in which the drone's materiality contributes in significant ways to the phenomenon of ambiguity surrounding their use. In its approach, this research presents several important insights for future work on drones and the application of new materialism for such studies within Critical Security Studies, International Relations, and beyond. This section explores these insights and implications.

Internal-External Dynamics

This approach facilitated the novel exploration of the drone and its relationship with ambiguity from its external manifestations to its intricate internal dimensions. Each iterative research phase took the exploration of the phenomenon of ambiguity a step closer to the object of the drone itself (through its modification potential both physical and digital, to its cyber foundations and internal functioning). This novel approach was facilitated by the initial TA, which exposed key areas relating to ambiguity and the physicality and digital aspects of the drone. These were then taken forward for deeper exploration. The resulting external-internal dynamic was illuminated through the integration of TA, new materialism, and a multi-phase research approach. This iterative process, moving from the external to internal manifestations of ambiguity pertaining to the drone, highlights a novel application of new materialism in the context of exploring complex socio-technical systems and their effects and implications. Moreover, this application of new materialism offers an exciting way to shape how we approach research into increasingly complex socio-technical systems in the age of AI, where the internal capacities at play require new thinking in how we approach epistemological explorations of their socio-technical implications.

Material focus

The integrated approach taken in this work offered a way to explore the broader themes of ambiguity pertaining to the drone, while facilitating a material-oriented focus to explore the problem-space. This allowed for the wide capture of relevant patterns and themes pertaining to the overarching phenomenon of ambiguity, followed by the more granular and detailed exploration of the material components, dynamics, and relationships at play within them. This dual aspect was important as it ensured that while material factors such as the drone's configuration, technical components, and

physical and digital modifiability were foregrounded in the analysis and interpretation, other important areas playing a role were also captured.

The foregrounding of the technical and material components and their relationships to ambiguity in the analysis were important to this work, which sought to fill a gap in the drone discourse. As outlined in the literature review, work looking at aspects of both drone modification (Cronin 2019), and ambiguity in relation to drone use in subthreshold environments (Hwang 2021; Mumford 2020), crucially overlook the role of the drone's physical configuration, cyber foundation, or other inherent properties in shaping effects and attributes surrounding this technology's use. Thus, these studies present an incomplete view of the dynamics at play, and the implications involved. This oversight is increasingly essential to address given the pace of change around drone innovation, which continues to push drones to new forms, functions, and applications. By foregrounding these dimensions in its analysis, this work addresses this lapse and provides a vital window into some of the – to channel Latour - *missing masses* from this emerging part of the drone discourse (Latour 1992).

Reflexive TA emphasises the role of the researcher in the interpretation of findings, taking into consideration the choices, theoretical orientations, and assumptions that guide how the research process unfolds and its interpretation of findings. This reflexivity was important in relation to understanding the impact of foregrounding certain factors over others in the analysis. Driven by key gaps in the literature, this work prioritised analysis of the technical, physical, and digital properties of the drone. This focus intends to balance the existing literature, which has a predominant focus on social, legal, and ethical facets in relation to the drone, its effects, and implications. It is in this context that the research enriches the broader discourse on drone technology, contributing to a more complete understanding of the properties underpinning its role in producing effects and shaping events.

Bridging Disciplines and Addressing Multifaceted Problems

The research design was effective for exploring a complex problem space. It allowed for three connected, yet underexplored, areas to be brought into dialogue in a structured way. The overarching problem-space entailed exploration of the phenomenon of ambiguity as it pertains to drones. The work was interested in first ascertaining in what ways we can observe this phenomenon, followed by understanding the factors and properties that might play a part in it. In scoping the research problem, this brought three areas into focus: ambiguity surrounding drone use in subthreshold environments; the evolution and changing nature of drones; and the capacity for drones to play a role in shaping phenomena or events. This research and its design brought these areas into dialogue, allowing for a unique exploration of the material properties, capacities, and dynamics inherent to the drone and the phenomenon of ambiguity surrounding aspects of its use. The multi-phase research approach allowed

for exploration of each key area, highlighting key themes pertaining to ambiguity through the TA process, while the integration of new materialism exposed the granular properties, attributes, and dynamics playing a role in, and shaping, ambiguity. Overall, the research demonstrates how new materialism can be applied in new ways to explore complex socio-technical systems and phenomena relating to their use.

8.2 Contributions and Implications

Drone technology has transformed the landscape of contemporary security and conflict, facilitating new means for both state and non-state actors to exert their will at a distance. The accessibility of drone technology, its versatility, and enduring promise of increased certainty through accuracy, precision, and information has made it an appealing tool for a spectrum of uses. Yet, we have entered a complex new era of drone use that challenges the perceived certainty such tools can offer. Today, drone use is typified by an expansive and growing drone userbase, diverse missions and objectives, vast modification potential, and varying technical applications spanning civilian and military contexts. This is occurring in synchrony with the rapid evolution of drone designs, functions, and capabilities, and the plethora of new applications and practices these evolutions introduce. These converging complexities present profound challenges to our conventional understandings of this device, its applications, and the emerging practices of use surrounding it. This is exemplified by the increasingly ambiguous ways in which drones are being used on the international stage. Today, we continue to see drone incidents characterised by anonymity, attributional issues, confusion, and deniability (BBC News 2024). We are ill-equipped for the emerging complexities of the drone's increasing plurality and ongoing evolution, and we are yet to fully understand it. These challenges have remained insufficiently explored in International Relations and Security Studies. This work begins to address this critical lapse by examining the phenomenon of ambiguity through the empirical site of the drone, interrogating the unprecedented plurality and complexity that defines this new age of drone technology.

While technology is often conceptualised and adopted as a solution to the uncertainties of war and armed conflict, this work aligns with the view that technology cannot fully eliminate the 'fog'. Using the exemplar of the drone, this work argues that emerging and disruptive technologies increasingly amplify and exacerbate uncertainties through the ambiguity they generate. Through a material-oriented exposition of the drone's properties and attributes, this thesis exposes, for the first time, the technology's material assembly as an inherently ambiguous device. It demonstrates how the drone actively contributes to the production of ambiguity in the international arena, ultimately amplifying rather than diminishing uncertainty in the security and conflict landscape. In doing so, this thesis reframes the drone as a device possessing a unique agentic capacity to shape perceptions, complicate

attribution, and generate ambiguity that can cause confusion, exacerbate uncertainty, and stymie effective responses. This thesis presents three core conceptual contributions to the field of Security Studies that advance our understanding of drone technology and its implications for security: the development of the Liminal Assemblage lens, the introduction of Drone Plasticity, and the concept of Remote Physical Presence. Cumulatively, these innovative new concepts expand our understanding of the contemporary drone and expand the utility of ambiguity as a concept for approaching the complexities of emerging and disruptive technologies like the drone. These concepts expose how ambiguity pertaining to drone use is not simply a by-product of human strategy or operational context, but is actively produced and perpetuated through the material and relational properties of the drone itself. In doing so, the concepts developed in this work provide a framework for conceptualising how drones shape and reshape security landscapes through the multifaceted ambiguities they generate. The following sections present these concepts, demonstrating how they advance our understanding of the contemporary drone and exploring their wider significance and implications for theory and practice.

8.2.1 The Liminal Assemblage

Central to this thesis is the introduction of a novel conceptual lens – the *Liminal Assemblage*. This conceptual development offers a transformative way of understanding the complex interplay of the drone's intrinsic and extrinsic properties, the phenomenon of ambiguity, and emerging practices of drone use on the international stage. It highlights the drone's capacity to blur and traverse a multitude of conventional boundaries and categorisations and provides a powerful framework for understanding the ambiguities these intersections create. The liminal assemblage challenges existing frameworks of understanding and interpretation by exposing a broader set of properties and interactions that permit the drone to blur several categorisations beyond the military-civilian dualism which has been widely acknowledged in literature on the dual-use nature of drone technology (Schulzke 2019; Novitzky, Kokkeler, and Verbeek 2018) . This lens illuminates how the drone's intrinsic properties of plasticity and cyber-physicality, coupled with the extrinsic property of ubiquity, interact and come together to produce a plurality of competing narratives – and thus *interpretations* – pertaining to drone functionality, purpose, operator, and origin. It exposes the drone as a device that finds itself at the threshold of multiple boundaries of interpretation: between offensive and defensive use, armed and unarmed use, friendly and hostile use, legitimate and illegitimate use, physical/kinetic use and cyber/digital use, and even remote-controlled and autonomous use. The liminal assemblage emphasises the drone's capacity to blur a multitude of boundaries, defying singular categorisations and challenging conventional notions of purpose and function across contexts. It helps us to think differently about the contemporary drone by providing a way to unpack its pluralistic nature in a more nuanced way and in exposing how these various pluralities can give rise to ambiguity. In turn, it allows us to consider how these ambiguities converge in ways that compound attributional issues and

confound cognitive capacities to determine intent, capability, and legitimacy. Accordingly, the liminal assemblage conceptualisation offers a crucial window into the drone's active role in the production of ambiguity within contemporary security and conflict landscapes.

This conceptual development makes a significant contribution to the emerging dialogue between International Relations and New Materialism by expanding our understanding of how the properties and attributes of complex socio-technical systems such as drones can play an active role in the shaping of perceptions, behaviours, outcomes, and decisions on the international stage. It is in this context that the work extends the drone discourse within Critical Security Studies (CSS) around agency and drone technology where scholars have sought to bring attention to the potential for drones to produce *things or effects* beyond their initial purposes (Grayson 2016b; Meiches 2017b). The liminal assemblage provides a tangible way to explore the drone's ability to 'act' through the ambiguity it generates; an effect that transcends the original design and intentions of the device. It highlights how ambiguities and pluralities inherent to drone technology can produce unintended effects that complicate their use while at the same time challenging our understandings of agency and purpose. Indeed, the drone's production of ambiguity as explored through the liminal assemblage represents a form of excess; an unintended effect produced by the interactions of components within the liminal assemblage and holding the capacity to influence decision-making, perceptions, actions, and outcomes. This challenges the assumption that technology is a neutral tool and demonstrates how technological properties and attributes, in addition to external factors, can shape behaviours, outcomes, and decisions in ways not anticipated or intended. The conceptualisation provides a new conceptual framework for understanding drones and their impact on international security by exposing how ambiguity is now increasingly purposefully exploited by actors across various domains, contexts, and uses.

A material understanding of the drone as a liminal assemblage allows us to approach the phenomenon of ambiguity around drone use from a new perspective that goes beyond existing considerations. Rather than treating ambiguity as a given, or as a by-product of ambiguous grey zone and hybrid warfare environments as some scholars have tended to (Hwang 2021; Carlucci and Mumford 2023; Mumford 2020), this research repositions ambiguity as an active phenomenon shaped by the drone's material properties and dynamically interacting with the environments within which they operate. This perspective moves away from human-centric understandings of ambiguity where ambiguity is understood primarily as a product of human strategy in grey zone and hybrid warfare. The liminal assemblage challenges this. It moves towards an understanding that recognises the active role technological tools can play in *producing and maintaining* ambiguous conditions. This change is important because rather than ambiguity pertaining to drone use being solely a result of human strategy or conflict environments, or being confined to specific actors, it exposes how ambiguity is

generated, shaped, and perpetuated by the properties inherent to the device itself and the material and relational capacities associated with it. This understanding further explains what we are observing in terms of the increasing transferal of ambiguity by the drone into domestic and civilian security contexts. The liminal assemblage broadens the conceptual utility of ambiguity beyond grey zone and hybrid warfare by exposing how the strategic use of ambiguity is becoming embedded in global security contexts through the very tools increasingly adopted within them.

The liminal assemblage further expands our understanding of how material and technological properties of tools like drones can shape security practices and actor behaviour in complex ways. While scholars of International Security such as Cronin begin to pay more attention to the attributes of technologies and the role they can play in making certain tools more attractive for use than others, these attributes are observed at a broad level rather than being unpacked and explored in fine detail (Cronin 2019). While such work provides an important starting point for closer analysis of technological attributes and their role in shaping actor behaviours in the international arena, it does not provide a full reading of what is happening, why, or how, when looking to these technologies and tools and their implications for international security. Using the drone as the exemplar, this thesis demonstrates the value of taking a more granular, material-oriented approach to exploring technologies and their intrinsic and extrinsic properties. Indeed, as the liminal assemblage illustrates, doing so assists in illuminating the finer mechanisms underpinning certain practices; shifting our focus from the practices themselves to the very building blocks that *enable* them. This can be used to inform more comprehensive understandings of why certain tools may be adopted, and how they are leveraged to achieve certain effects. Only then can we begin to efficiently plan, safeguard, and defend against the emerging challenges such tools introduce.

8.2.2 Drone Plasticity

The concept of *Drone Plasticity* established in Chapter 5 marks another central conceptual contribution of this research. In introducing a way to conceptualise complex objects that have the capacity to be both extrinsically modified, and to intrinsically self-modify through their autonomous functionality, this concept extends existing new materialist conceptualisations of object-agency. Thus far within the new materialist discourse on objects, no such conceptualisation attends to objects with some level of self-determinism and the capacity to modify their own behaviour or physical form. Indeed, Law and Singleton's work in 'Object Lessons' presents different approaches to understanding objects and their capacity to 'act' and change, with conceptions of boundary objects, fluid objects, and their later introduction of fire objects (Law and Singleton 2005). However, complex cyber-physical devices such as drones do not fit neatly within these existing frameworks for classifying and understanding objects within the broader new materialist discourse. As such, plasticity – and the

notion of the *plastic object* – offers an extension to current classifications of objects that captures both the intrinsic and extrinsic capacities for cyber-physical objects such as drones to be vastly changed and modified, including self-modification. This conceptual development provides a way to critically rethink how the vast modification potential of disruptive technologies like drones interacts with, disrupts, and alters traditional notions of object-agency. In doing so, this work expands how we can think about agency and objects like drones, which actively exhibit the capacity to dynamically interact with, reciprocally transform, influence, and reshape the security landscapes they inhabit. Further, it provides a crucial lens for the broader study of other emerging and disruptive technologies where autonomy and the ability to self-modify are becoming defining features. Importantly, however, the argument around agency and plastic objects such as the drone does not reside simply in the notion of autonomous functionality as a form of agency. Rather, the link between drone plasticity and agency lies in how the drone's vast intrinsic and extrinsic modification potential further complicates and blurs the boundaries and categories found within the liminal assemblage. Autonomy adds extra layers of complexity to these already complex challenges, frustrating the way drones may be understood and interpreted in international security contexts. Ambiguity is actively produced and shaped by the drone's intrinsic properties, including its plasticity, creating a situation where agency does not reside in the device's autonomy, but rather in the ambiguities it creates. The interplay between plasticity and ambiguity within the liminal assemblage enriches our understanding of the drone's agentic capacity by going beyond simply recognising the drone's increasing autonomy and showing instead how the vast modification potential of the device, including aspects of its autonomous functionality, *fuel ambiguity*. It is within this context of ambiguity, produced by the complex interactions within the liminal assemblage of the drone – that agency is situated in this work.

Drone plasticity further extends the broader drone discourse, particularly pertaining to drone modification. Jackman's consideration of the drone's "malleability" calls for greater attention to the device's capacity to be modified and repurposed to new form and functions (Jackman 2019). The concept of drone plasticity developed through this work extends this conversation, moving beyond the notion of malleability by attending to not only the external capacities for the drone to be modified, but to the intrinsic and internal digital life of the drone and its capacity for both intrinsic modification and self-modification. This extension is significant as it encapsulates the indelible changes involved in intrinsic digital modification and transformation that have until now been insufficiently explored. Digital changes to the drone – whether through software updates, algorithmic evolution, or other intrinsic modification – indelibly alter the drone in ways imperceptible to the user. This dimension of the drone's modification potential is not captured by conceptualisations like malleability. Plasticity remedies this oversight. This conceptual shift is important because plasticity exposes the layers of ambiguity that the drone's vast modification potential adds, complicating the task of understanding a drone's true capabilities and to define its role or purpose in security contexts. Plasticity captures the

drone's capacity to transform physically and digitally, creating conditions where traditional understandings of its purpose and capability no longer hold. It highlights that ambiguity – with plasticity as a key driver – is now an essential component of the drone, holding the capacity to frustrate clarity and generate the perfect conditions for the strategic exploitation of ambiguity.

8.2.3 Remote Physical Presence

Integral to our understanding of the drone as an ambiguous device is the concept of *Remote Physical Presence* developed through this work. As argued throughout Chapter 6, the drone is a cyber-physical system that inherits ambiguous properties from cyberspace. It operates as an extension of the cyber domain in the physical world, increasingly exhibiting many of the attributional challenges and opacities of determining operator, origin, purpose, capability, and intent that we see in cyber operations. By reframing our understanding of the drone as both a cyber-physical system and a physical manifestation of the cyber domain, the concept of Remote Physical Presence captures the drone's capacity to exert influence across both the digital and physical domains. This presents a challenge to our conventional understandings of presence and also of agency, creating a complexity where both are no longer tethered to physical proximity and human interaction. This reframing is significant as it exposes the drone's capacity to blend and blur these two distinct realms, creating new layers of ambiguity that further frustrate our capacities to know the device, its capabilities, and purpose.

The concept of Remote Physical Presence extends discussions of drones in International Relations and Security Studies through deepening our understanding of presence and agency pertaining to the drone in security and conflict contexts. Much of the existing scholarship has focused on the absence of physical human presence in processes of drone surveillance and targeted killing, through conceptualisations such as absentee warfare and remote warfare (Knowles and Watson 2018). Moreover, scholars including Gregory (2011b) and Agius (2017) for example, have taken as a central focus the drone's capacity to allow power projection and control from a distance, without human engagement within the physical contexts where surveillance and violence takes place. However, where much of this existing work focuses on the idea of physical absence and the removal of the operator from action, the concept of Remote Physical Presence complicates these conventional ideas through its emphasis on drone presence and its influence as a cyber-*physical* entity. It highlights that the drone is not simply a remote tool in the hands of an operator, but a physical entity that itself exerts influence across both its digital and physical dimensions. This conceptual shift begins to redefine the notion of presence in the age of complex socio-technical, cyber-physical devices such as the drone. While indeed drones still enable remote, or absentee action, their cyber-physical nature allows them to manifest a unique form of agency that influences and 'acts' independent from its operator's

immediate context. In capturing this, Remote Physical Presence helps elucidate the disruptive influence of the contemporary drone we increasingly see today, where the drone's mere presence alone can cause vast disruption untethered to the operator's identity or intent. Contrasting with earlier scholarship that focuses on drones as instruments of statecraft or human strategy, this research exposes how the drone's presence itself can generate strategic ambiguity that disrupts, induces uncertainty, and complicates responses regardless of who the operator behind it is, or what their intent might be. Remote Physical Presence contributes to the drone's agentic capacity – its capacity to act (whether in causing confusion, disruption, or certain responses to its presence) even without any clear attribution or understanding of its purpose. The sheer possibilities attached to the device – through its cyber-physicality, plasticity, and ubiquity – conjure an inescapable ambiguity with the capacity to influence and shape situations on the ground. We can observe this influence occurring time and time again, from the inception of this project where the Gatwick Drone incident dominated headlines (BBC News 2018a), to the present day where unidentified drones continue to harass U.S airbases in the UK (BBC News 2024), and where numerous drone sightings in New Jersey spark confusion and fear as their origin and intentions remain ambiguous (Meyer and Chavez 2024). Regardless of who is behind these incursions, the drone - and the *many plausible narratives* it gives rise to through its extrinsic and intrinsic properties – continues to cause disruption in security contexts through the very ambiguities it conjures. The concept of Remote Physical Presence sheds more light on the drone's complication of traditional notions of attribution and accountability, particularly when we take into consideration the drone's duality as both a cyber and physical attack vector. This duality introduces further complexity by obscuring abilities to understand the device's capabilities, purpose, and potential effects; ambiguities which may be exploited by nefarious actors. The concept of Remote Physical Presence repositions the drone as an ambiguous actor that inherits and amplifies the ambiguities of the cyber domain into the physical world. This fresh perspective reshapes our understanding of agency and presence in both the physical and digital domains as cyber-physical systems such as drones increasingly saturate society.

The original concepts developed through this research - the Liminal Assemblage, Drone Plasticity, and Remote Physical Presence – contribute to elucidating the emerging complexities of the new era of drone technology. This new landscape is typified by plurality, from an expansive and continually growing drone userbase, the multifaceted evolution and modification potential of drones giving rise to new applications, contexts and practices of drone use, to the deepening complexity of the drone as a device at the nexus of the cyber and physical domains. These pluralities can introduce unprecedented levels of ambiguity around the drone and its use. The ramifications of this are only beginning to be felt in the international arena as we see the growing trend of deniable drone use, disruption and confusion, and stymied responses to drone events. This research elucidates the underlying mechanisms, properties, and interactions giving rise to such effects in the international system,

exposing the pluralities both inherent to the technology itself, and surrounding it through its increasing ubiquity. Attaining a deeper understanding of how the drone's properties and attributes facilitate certain deceptive practices and uses is important as drone technology continues to evolve. We must be cognizant of the ways in which this, and other cyber-physical devices, may be intentionally designed going forward in ways that exacerbate existing challenges around attribution and accountability. Findings from this research ultimately highlight the necessity for a fundamental shift in how we approach, anticipate, train for, and respond to this device and its use. As the adoption of drones continues across all areas of both civilian and military domains, this work calls for greater scrutiny of the emerging challenges we face as our society becomes increasingly saturated with cyber-physical devices with the capacity to introduce more uncertainty than they aim to eliminate through the multifaceted ambiguities they generate.

8.2.4 Broader Implications for Theory

In pushing the boundaries of how we conceptualise technology, agency, and ambiguity in the modern landscape of drone use, this research makes significant contributions to theoretical innovation in International Relations and Security Studies that hold broader implications for future research and theoretical development. This section details these implications, from its potential to reinvigorate thinking on strategic ambiguity in the defence and security context, to the utility of incorporating a dual-lens framework in new materialist approaches to understanding complex socio-technical systems.

A Theoretical Foundation for Future Technological Analysis

The conceptual developments made through this work – the liminal assemblage, drone plasticity, and remote physical presence – provide us with a foundational template for understanding and analysing a plethora of other emerging and disruptive technologies such as AI systems, innovations in robotics, lethal autonomous weapon systems, and additive manufacturing. In providing the foundations for how we can begin to approach the complexities of innovations that exhibit inherent pluralities, and which blur the boundaries between multiple categorisations, this work lays the groundwork for more nuanced analyses of other disruptive technologies that may begin to saturate our societies in a similar way as drones are today. Furthermore, these conceptual frameworks can be extended to incorporate the wider array of socio-technical, socio-political and legal facets that underpin the technologies and their use we see on the international stage. For example, the liminal assemblage serves as a basis for how we can see material and relational properties of a technology interacting to produce ambiguity. However, it does not profess to be the only set of interactions at play in the complexity of the drone. On the contrary, it is one subset – with a focus on the technological material properties and how these

interact with the phenomenon of ambiguity. Ultimately, the premise can be adapted to explore how different sets of properties interact and relate to produce effects or phenomena in the use of different technologies in the international arena, providing an important foundation for such explorations.

Rethinking Strategic Ambiguity in The Era of Disruptive Technologies

The concept of strategic ambiguity holds renewed relevance in the contemporary defence and security environment amid an increasing turn to the use of complex remote-physical technologies within these contexts. As previously mentioned, while some scholarly work has recognised the potential for ambiguity in connection with drone use, these instances have been limited to acknowledgement and observation rather than detailed exploration (Mumford 2020; Hwang 2021). In addition to this work extending thinking on the phenomenon of ambiguity pertaining to the drone, it also provides a new lens through which to reinvigorate discussions around strategic ambiguity in the era of disruptive technologies like drones. The concept of strategic ambiguity is well recognised in the context of nuclear deterrence, principally through the pioneering work of Schelling and Baylis (Baylis 1995). However, there is a need for closer consideration of the concept of strategic ambiguity in conjunction with increasingly ambiguous tools and technologies. This research identifies mechanisms through which ambiguity can be constructed through intrinsic properties inherent to the drone, and extrinsic drivers with the potential to magnify these ambiguities. This allows us to unpack how ambiguity can be produced, heightened, leveraged, or exploited, facilitating a greater understanding of how threat actors are approaching the use of drones in various contexts. The material-oriented approach this work has taken holds value for the exploration of strategic ambiguity and the role that other technologies and their fundamental properties may play in both the construction and maintenance of ambiguity in the international arena. The discourse on strategic ambiguity requires fresh thinking in the era of modular, accessible, and remotely operated technologies – where the intentional embedding of ambiguous traits into tools used within conflict and security is a very real concern going forward. This work's elucidation of the active role the drone can play in the production of ambiguity is an indication of the necessity for more nuanced critical approaches to interrogating the technologies and tools we are increasingly adopting in both civilian and military domains.

Extending New Materialist Approaches

This research offers a way to rethink how we can apply New Materialism to the study of complex socio-technical objects such as the drone in International Relations and Security Studies. The extrinsic-intrinsic approach which emerged throughout the development of this work demonstrates how we can apply new materialist thinking to complex socio-technical problems in new ways. Starting with a broad (external) exploration of a phenomenon such as ambiguity and drone use exposed other internal properties that required exploration to explain the phenomenon under study.

This led to what became an extrinsic-intrinsic exposition of the drone's material agency in the phenomenon of ambiguity, introducing a dual-lens approach which developed a layered approach to the exploration of the drone's agency. This facilitated the exploration of intrinsic agency - stemming from properties like the drone's plasticity and cyber-physicality - and extrinsic agency arising from the drone's external relational interactions with the environments and contexts it operates within, including its growing ubiquity and strategic modification and exploitation by nefarious actors. This approach introduces new ways that we can begin to apply new materialism to understand complex phenomena emerging in relation to the use of disruptive technologies on the international stage in a more granular and nuanced way. The dual approach of extrinsic to intrinsic allowed for the extension of object-agency to cyber-physical objects and facilitates the exploration of the drone's intrinsic digital processes alongside its physical attributes. This approach helps us to see the drone as more than just a tool used by humans – but something where agency is no longer solely tied to human interaction with the device, but also encompasses the self-modifying capacities of the device itself. The extrinsic-intrinsic approach offers an innovative way to examine complex socio-technical systems, engaging them as dynamic and hybrid entities which comprise both technical material properties and material properties in relation to their wider relational capacities. This dualism offers a new level of granularity to New Materialist analysis by allowing for a more nuanced interrogation of how technologies actively shape environments and interact with human strategies in new ways.

Furthermore, by bringing into dialogue three important, yet underexplored dimensions of drone technology – its modification and evolution, its capacity to 'act', and its emerging relationship to ambiguity in conflict – this work highlights the cross-disciplinary impact that material-oriented approaches hold for broadening the agenda within International Relations and Security Studies. Indeed, this work speaks not only to the drone discourse within security studies and critical security studies, bringing to light new ways in which we can understand the drone's agentic capacity in the international arena, it further speaks to drone studies within wider fields including strategic studies, shedding new light on the nuanced dynamics at play underscoring plausibly deniable drone usage. Moreover, it speaks to the wider drone discourse beyond international relations, adding important insights into the ongoing evolution of drone development and modification. These insights were attained through the material-oriented approach taken, highlighting its efficacy beyond the realms of CSS. This opens up the potential for future research within disciplines and areas not typically associated with new materialist perspectives, paving the way for more material-oriented explorations of strategic effects and the technologies that produce them.

8.2.2 Broader Implications for Practice

Further to theoretical implications, this work holds several implications for practice. This section details these practical implications, spanning defence planning and strategy, technological development, and policy and regulation implications.

Security and Defence Planning

Elucidating a finer understanding of how ambiguity can be purposefully leveraged and exploited through devices such as the drone holds significant strategic implications that require high-level preparedness in the defence and security context. This is increasingly important as drone adoption continues to expand across multiple domains and contexts and as their capabilities evolve. This work has brought to light the multiplicity of ways drones may elicit ambiguity related not only to attribution and the obfuscation of operator identity, but also to confusing perceptions and interpretations over purpose, intent, legitimacy, and capability. Recognising this potential can assist in developing better counter-strategies and mitigations against threats from drones, reducing vulnerability to ambiguous drone incidents.

The drone is a device that is non-static. It is continually evolving and increasing in its complexity, with practices and behaviours around its use expanding in sync with it. Our thinking needs to expand at the same pace. Today we are faced with a reality where merely a single drone can conjure levels of ambiguity that incapacitate our ability to coordinate effective responses and to determine what the device is capable of, and what its purpose might be in a given context. The emergence of swarming is poised to introduce the possibility for multiple drones to be tasked with multiple *different missions* and carrying *different payloads* simultaneously. Heading into this future, we must be better prepared for assessing the drone's influence and effect on decision-making and response at scale. Doing so will facilitate a better state of preparedness to minimise the potential of strategic or technological shock pertaining to drone use as we move forward. Understanding the effects of ambiguity connected to purpose and capability on decision-making and responses is invaluable, and the work presented throughout this thesis provides an essential foundation for developing this understanding further as advances in drone technology introduce even more uncertainty into our defence and security landscapes.

Technological Development and Regulation

The material exposition of ambiguity this thesis has put forward highlights emerging challenges poised to frustrate existing issues relating to attributional ambiguities and inabilities to determine

drone capabilities, purpose, and functions. Additive manufacturing (3D printing) is one example, holding the potential to exacerbate attributional challenges surrounding both physical and digital traceability surrounding drones. As the desire to build-in ever-more flexible and modular options into dual-use technologies like drones grows, we must be cognizant of the unanticipated consequences that modularity and flexibility introduces. Modularity holds the potential to build-in ambiguity at the seams of its flexible vision. Last-minute modularity to increase flexibility of drone use is envisioned to facilitate the switching of drone payloads depending on the needs of the situation or mission. This research elucidates how this flexibility also increases the capacity for ambiguity; eliciting multiple interpretations over drone capability and purpose in the eyes of the adversary. This introduces the possibility of misinterpretation and the potential for disproportionate or escalatory responses should intentions surrounding drone use and presence be misconstrued. Consequently, we must pay more attention to the inherent ambiguities potentially being inadvertently *built in at the seams* through concepts such as mosaic warfare and modularity, which may bring about unwanted levels of ambiguity in the environment within which it is being applied.

This introduces a clear necessity for better regulatory frameworks going forward that can help tackle the challenge of ambiguous drone design, production, and use. For example, transparent classification standards could be introduced at the point of manufacture, where producers are required to include built-in classification markers to specify a drone's operational scope and capabilities through unique IDs or software tags. This could be introduced as a priority in relation to drones with modular payload capacity and which have autonomous functionality, introducing a certain level of verifiable information about a drone's scope, functionality, origin, and operator. This could assist in reducing ambiguity and lowering the risk of misinterpretation.

Security Training and Adaptive Frameworks

The inherent plurality and ambiguity this research exposes in relation to drone technology necessitates new training paradigms for security practitioners to ensure we keep pace with this fast-paced device and the emerging practices of use surrounding it. As the drone continues to evolve, becoming more customisable, more autonomous, and potentially produced through unconventional manufacturing methods – tracking, identifying, and tracing drone use is set to become even more complex alongside capacities to understand capability, purpose, and intent. Findings from this work demonstrate the need for a shift beyond static categorisations of drones based on pre-determined parameters like size, altitude, speed, and observable payload, to more dynamic and adaptive frameworks that take into account the unfolding plurality of this device. Dynamic Threat Assessment Models (DTAM) may be one way to move towards this. These could be developed and incorporated into security protocols

through the integration of real-time data and AI-driven analytics – taking into consideration environmental and contextual data – in order to better assess and respond to drone threats in real-time.

Similarly, it is evident that clearer protocols need to be designed and implemented in order to fortify response strategies for drone incidents at both the domestic and international level. The events that unfolded during the Gatwick drone incident illustrate the shortcomings of response strategies in such circumstances. Responders were ill-equipped at every level to deal with the ambiguity of this situation. The official debrief report states that both the airport and responding teams from Sussex Police would have been better able to respond given clear information about *how* to respond to such an event, the availability of mitigation measures, and clearer guidance on how responsibilities should be divided among the commercial sector, government, and police (College of Policing 2019, 8). Findings from this research can help to inform and develop interactive and immersive scenario-based training exercises that may be able to increase preparedness for ambiguous scenarios involving drones. Such exercises can be used to prepare and inform the development of adaptive response strategies to more effectively traverse the varying levels of difficulty arising in distinguishing crucial information about drones in different contexts. Training exercises of this nature could be utilised, for example, to challenge practitioners to respond to varying scenarios, assessing their impact on decision-making and response – from unknown drones loitering near restricted CNI, rapidly changing drone swarms executing different missions with different payloads and capabilities, to hybrid cyber-physical threats where drones are being used for both kinetic and digital intrusion. In addition to this, such exercises could inform the development of a *standardised incident playbook* that outlines clear steps and actions for use in response to drone incidents where ambiguous conditions abound. This should include clear procedures for how different scenarios can be responded to, including things like appropriate guidance on the allocation and sharing of responsibilities among different parties to the response, and clear public communication strategies to help minimise misinformation, panic, and unhelpful speculation that can further compound responses and cause confusion through conflicting accounts and reports in the media.

The contemporary drone – a cyber-physical system operating across a spectrum of contexts and domains – epitomises the ambiguity inherent to the contemporary landscape of conflict and security. Through an exploration of the drone's ubiquity, vast modification potential, and emerging utility at the nexus of the cyber and physical realms, we gain insight into the ways in which the drone is both *rendered* ambiguous and *engenders* ambiguity in the international arena. Drawing on New Materialist thought, this research illuminates the drone's intrinsic plasticity and cyber-physicality, exposing the depth and plurality of how the drone is *materially assembled* as an ambiguous device. These properties contribute to the development of a conceptualisation of the drone as a *liminal assemblage*, arguing for an understanding of drones that foregrounds its capacity to blur and traverse conventional

boundaries and categorisations while simultaneously conjuring a multiplicity of plausible interpretations pertaining to functionality, purpose, operator, and origin. This understanding underscores the necessity for wider consideration of how the drone's ongoing evolution can shape international dynamics, actor behaviour, and strategic outcomes through their novel modes of influence and effect – with the generation of ambiguity at the forefront.

In so doing, this work contributes to the emerging discourse between international relations and new materialism, bringing to light new ways in which we can observe complex socio-technical systems such as the drone shaping the international through the effects it can produce. It is within this context that the work bridges a crucial gap between conversations around drone modification and evolution, the drone's capacity to 'act', and discussions around ambiguity in conflict. In exposing the ways in which the drone's intrinsic properties actively contribute to the production of ambiguity, this work argues for a more nuanced understanding of the drone's capacity to give rise to novel modes of influence and effect. In so doing, this work offers a unique contribution to the ongoing drone discourse within Critical Security Studies (CSS), bringing into focus the drone's agentic capacity to shape perceptions, dynamics, actions, and strategic outcomes on the international stage through the production of ambiguity. Understanding the drone's latent ambiguous potential holds important implications for international security, and the research conducted throughout this thesis provides a crucial benchmark for reconceptualising the influence of complex remote-physical technologies in the international arena going forward.

Abbreviations

AI – Artificial Intelligence
AMD – Air and Missile Defence
ANT – Actor Network Theory
C2 – Command and Control
CNI – Critical National Infrastructure
CPS – Cyber Physical System
CSS – Critical Security Studies
DTAM – Dynamic Threat Assessment Model
FANET – Flying Ad-Hoc Network
GCS – Ground Control Station
GPS – Global Positioning System
IO – International Organisation
IoD – Internet of Drones
IP – Intellectual Property
ISR – Intelligence Surveillance and Reconnaissance
LAWS – Lethal Autonomous Weapon Systems
MALE – Medium-Altitude Long-Endurance
ML – Machine Learning
PMC – Private Military Contractor
SDK – Software Development Kits
SOF – Special Operations Forces
TA – Thematic Analysis
UAS – Unmanned Aerial System
UAM – Unmanned Aerial Manipulators
UAV – Unmanned Aerial Vehicle
UUV – Unmanned Underwater Vehicle
VUCA – Volatility, Uncertainty, Complexity, Ambiguity
WoT – War on Terror

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