Article:
Lockhart, A., While, A., Marvin, S. et al. (2021) Making space for drones: the contested reregulation of airspace in Tanzania and Rwanda. Transactions of the Institute of British Geographers, 46 (4). pp. 850-865. ISSN: 0020-2754

https://doi.org/10.1111/tran.12448

Accepted: 11 March 2021

DOI: 10.1111/tran.12448

REGULAR PAPER

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Making space for drones: The contested reregulation of airspace in Tanzania and Rwanda

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Funding information
British Academy- KF1\100069.

In contrast to their use in warfare and surveillance, there is growing interest in the potential of "drones for good" to deliver societal benefits, for example by delivering medical products and other essential goods. Yet development of medical and commercial delivery has been limited globally by restrictive regulation to protect airspace safety and security. In this paper we examine how certain African countries have become testbeds for new forms of drone infrastructure and regulation, driven by the overlapping interests of governments, drone operators, and international development agencies. In particular we explore the factors that have led to the development of an advanced medical delivery network in Rwanda and contrast that with the closing down of airspace for drones in Tanzania. The paper makes a distinctive contribution to research on the ongoing constitution of dronespace as a sphere of commercial and governmental activity. Rwanda's drone delivery system is seen as the forerunner for the wider enclosure and parcelling up of the lower atmosphere into designated drone corridors that limit the democratic and disruptive potential of drone activity in line with prevailing logics of airspace regulation.

KEYWORDS
airspace regulation, drones, enclosure, infrastructure, Rwanda, Tanzania

1 | INTRODUCTION

The proliferation of drones – otherwise known as unmanned aerial vehicles (UAVs), unmanned aircraft systems (UAS), or remotely piloted aircraft systems (RPAS) – has become a source of growing potential and anxiety in recent years. Drone research initially focused on surveillance, policing, and warfare (e.g., Gregory, 2011; Williams, 2011), but increasingly affordable drones are now creating opportunities to develop lower airspace as an infrastructural resource for a range of commercial, humanitarian, and civilian uses (Floreano & Wood, 2015; Klauser & Pedrozo, 2015). The possibility of establishing drone delivery networks for example, which might transcend poor or congested road infrastructure, has emerged as a particular area of interest and experimentation.

Yet there are major challenges in making, managing, and regulating space for drones. While the drone industry is vocal about the need for airspace to be reconfigured and made legible for commercial exploitation, governments have been reluctant to facilitate greater access to the skies due to anxieties over safety and security (Shaw, 2017). Numerous accidental but potentially fatal near misses with other aircraft, and major incidents such as the disruption of Gatwick Airport in December 2018 – by drones that were never identified, tracked, or brought down – have demonstrated the threats posed by "rogue" drones. Security concerns about rogue aircraft have been of greater regulatory significance ever since the 9/11 terrorist attacks in the USA. Drones are relatively easy and inexpensive to manufacture, buy, and operate, and therefore difficult to control compared to conventional aircraft. Although UAS traffic management (UTM) systems, "geofencing," and other technological "counter-measures" could substantially mitigate airspace risks, they are not yet fully developed or reliable (Jackman, 2019). In most countries drone use therefore remains tightly restricted, especially close to airports and flight paths, and pilots must maintain "Visual Line of Sight" (VLOS) with their aircraft, which vastly limits the potential for delivery systems.

Those seeking to progress the drone delivery agenda are looking at the development of some form of drone corridor infrastructure to enable the selective but controlled opening up of low-level airspace for registered operators. Crucially for our concerns in this paper, certain countries in Africa have emerged as important testing sites for these systems, often justified on humanitarian and development grounds by various global health and donor interests, national governments, technology firms, and NGOs (Sandvik, 2015). For these projects, using drones to bypass poor ground-based infrastructure has been positioned as a unique African opportunity, but there is also a sense that African countries might somehow be more flexible with airspace regulation than countries with more "developed" airspace management.

In this paper we focus on the selective opening up and closing down of commercially operated drone activities in Tanzania and Rwanda. Both countries have become key sites of "drones for good" innovation, with an interest in rewriting airspace regulation to manage the emergence of commercial dronespace – defined as a new frontier for enclosure and development, made up predominantly of Class G airspace operationalised by civilian drones, and the socio-technical systems that enable its use. In Tanzania, ambiguous regulatory authority initially enabled several emblematic mapping projects, but airspace regulators have gradually closed down space for drones in response to increasingly ambitious proposals for delivery projects, and specific concerns about risks of airspace safety. The Rwandan government meanwhile was quick in establishing a strict regime for prohibiting unregulated drone ownership and use, but subsequently worked proactively with US drone start-up Zipline to develop the then most advanced drone corridor network for the delivery of blood and medical products in the world. Zipline's drone infrastructure model has since been transferred to Ghana, and provided a socio-technical foundation for the development of innovative "performance-based" regulations for facilitating other kinds of Beyond Visual Line of Sight (BVLOS) drone operations in Rwanda. Drawing on qualitative research carried out in 2018[1] (funded by the British Academy "Drones/Robotics and Development Priorities in Africa: Transformative infrastructure or digital colonisation?" project), the paper examines the difficulties in reregulating airspace for drones and the factors that have supported and enabled innovation in Rwanda. The two examples, it is argued, are emblematic of wider struggles over the constitution of commercial dronespace, but also prefigure future enclosure of airspace for drones and raise important questions about proprietorial control by "trusted" drone delivery platforms.

The paper is structured as follows. First, we examine the nature of airspace regulation and its uneven development as an essentially risk-averse and hierarchical set of logics, institutions, and practices. Reviewing existing geographical literature on airspace and drones, we consider how the advent of cheap commercial drones has complicated and destabilised prevailing modes of airspace management and control and draw out the dilemmas faced by governments in selectively facilitating drone use while protecting airspace safety and security. The case studies are then situated in the context of "drones for good" initiatives in the global south and Africa as a particular site of technological and regulatory experimentation, followed by the two case studies of Tanzania and Rwanda, discussion, and conclusions.

Geographers have made a distinctive contribution to understanding these issues, reflecting interest in processes of enclosure, spatial regulation (of the skies), and notions of vertical and volumetric geographies (e.g., Adey, 2010; Budd, 2009; Dodge & Kitchen, 2004; Graham, 2016; Lin, 2017; Williams, 2011). There is a growing body of geographical drone research (e.g., Akhter, 2019; Garrett & Anderson, 2018; Gregory, 2011; Jackman, 2019; Kaplan, 2020; Klauser & Pedrozo, 2015; Sandvik & Lohne, 2014; Shaw, 2017), which this paper builds on in a number of ways. First, the paper extends literature on the new spatialities of dronespace by engaging in detail with the politics and practices of airspace regulation, highlighting the problem of "rogue" aircraft as a key point of tension that – in trying to "make space for drones" – regulators attempt to resolve through new spatial orderings, technologies, rules, and protocols. Second, we explore the contested constitution of Africa as a context for drone testing, and the factors that have enabled and constrained particular initiatives. Part of that story is about the internationalisation of robotic experimentation as start-up firms, innovators, and investors seek opportunities to test, demonstrate, and open new markets for their technologies and platforms. Yet while there are clearly postcolonial logics at play, we refute more simplistic Eurocentric notions of Africa as un(der)regulated testbed for drones. As the case studies demonstrate, African countries have been no more or less permissive than other countries around the world. Drone experimentation and operations in Rwanda are tightly controlled by the government, and the country's leading role in drone infrastructure development is made possible by a level of restriction over drone ownership that is not exercised in many other places. Third, the paper advances ideas of drones as infrastructure as constituted through the logics, technologies, and spatial relations of the enclosed drone corridor. We show how drone delivery is predicated on investment in (and returns on) securitised infrastructure solutions to regulatory dilemmas, which, while potentially resolving competing logics of enclosure, are likely to replicate the monopolistic and selective socio-spatial modes of existing aeromobilities, thus challenging claims about the drone democratisation of airspace.

2 | AIRSPACE (RE)REGULATION: MAKING SPACE FOR DRONES

Modern aviation and colonial airpower became a critical element of the constitution of Western societies, enabling new ways of seeing, traversing, and projecting power over territory and populations (Aaltola, 2005; Cwerner et al., 2009; Pascoe, 2001). Changing capabilities of aircraft have necessitated frequent regulatory and legal responses over the last century, through which struggles over airspace ownership, access, and control have played out (Adey, 2010; Budd, 2009). Development of military airpower during the First World War led to international agreement that enshrined national airspace control as an essential component of territorial sovereignty (Banner, 2009), and airports became key infrastructure for modern nation-building and trade (Adey, 2010). As global airspace emerged as an economic frontier, competing nations with strong aviation interests such as the UK and USA moved to shape a common regulatory regime for international air travel through bilateral and multilateral agreements (Budd, 2009; van Vleck, 2013). Aeromobility remains highly uneven, shaped by the legacies of colonialism and capitalist globalisation, and entrenched through imperial modes of governance exercised through the International Civil Aviation Organization (ICAO), created in 1944 (Debbage, 2016; Lin, 2017). Post-colonial Africa for instance still accounts for only a small fraction of global air travel, reflecting disparities in wealth, underinvestment in airspace infrastructure, and the continued dominance of intercontinental routes by airlines of former colonial powers (Pirie, 2014).

Although the lower atmosphere has become increasingly transnationalised through integrated air traffic control (ATC) and ICAO standards, national governments have retained strong sovereign control of national airspace (Adey, 2010; Budd, 2009). Market liberalisation since the 1980s allowed entry of new low-cost airlines, but despite struggles over its composition and distribution of rights, airspace remains risk-averse, tightly regulated, and hierarchically structured both internationally and within national states (Budd, 2009; Debbage, 2016). In terms of structure, airspace is highly complex and "more accurately exists as a plethora of vertically and horizontally overlapping intersecting airspaces and should thus be described in the plural" (Williams, 2010, p. 258). Airspace is divided first into large Flight Information Regions (FIR), under the jurisdiction of national or civil aviation authorities (CAAs). CAAs have overall responsibility for airspace regulation and safety, aided by ATC. FIRs are sometimes vertically segmented into upper and lower levels, while sections of FIRs are designated a "Class" A–G and mapped onto aeronautical charts. These are subject to differing ("instrument" and "visual") flight rules and decreasing degrees of control by ATC, where classes F and G are part of "uncontrolled airspace." Class G is the portion of uncontrolled airspace closest to the ground, where opportunities for commercial drone use are usually situated. This creates, as Budd describes, "a highly complex web of different control zones and sectors, all of which are effective between different altitudes, subject to different rules and regulations, and may only be active for certain periods of time" (2009, p. 119). This enables significant flexibility in response to changing circumstances, environmental conditions, and emergencies (Adey, 2013; Budd, 2009). Further complexity is added by numerous "special use airspaces" (e.g., sites of national security), where civilian aircraft are permanently or temporarily restricted or prohibited.

Although there is some national variation, CAAs operate in line with ICAO standards, which diffuse technologies and expertise developed in response to the gradual intensification of air traffic and challenges of maintaining airspace safety, specifically in the North Atlantic region (Lin, 2017). Standards cover design, manufacture, maintenance, and operation of aircraft and ground-based equipment, ATC protocols, and licensing of pilots, air traffic controllers, flight dispatchers, and maintenance engineers, as well as airports and navigational aids. These rules are necessarily encoded and enacted through complex socio-technical systems (Budd, 2009; Pascoe, 2001). For Dodge and Kitchen (2004; see also Budd & Adey, 2009), air travel means moving through continually co-constituted code/space, emphasising dependence on software in the contingent production of airspace. Others have highlighted the technologically mediated but vital role of human agency – by pilots, air traffic controllers, and so on – in the ongoing performance and practice of airspace under differing conditions (Adey, 2013; Lin, 2016; Williams, 2010). The risk-averse ordering and policing of the skies by ATC has a distinctly human logic of oversight and command (Budd, 2009). While the degree of automation has grown over the years, a precautionary approach and human override remain crucial to airspace safety, reflecting the limits of real-time aerial surveillance, human decision-making, and unruly materiality of the atmosphere (Lin, 2017).

Airspace regulation has developed through the slow accumulation of risk-averse standards and protocols in an increasingly complex set of environments. Despite socio-technical innovation and market liberalisation, a logic of strong centralised state control has persisted, reflecting the non-negotiable imperatives of maintaining safety and security. These relatively stable forms of regulation – aided by the high costs of aircraft and straightforward control of ground-based infrastructure – have been central to restricting airspace use and maintaining highly unequal geographies of aeromobility (Lin, 2017). The advent of drones presents a major challenge to these long-established modes and logics of airspace regulation, because of the vastly reduced costs to entry, increasingly heterogeneous operational capacities and associated difficulties maintaining oversight and control.

2.1 | Drones and the disruption of airspace

Drones are becoming cheaper to manufacture and operate, and are available – in principle at least – to an ever wider range of actors. Emerging from military technologies developed in the 1980s, the term "drone" has come to describe UAVs of all types, shapes, and sizes that operate without an on-board pilot (Klauser & Pedrozo, 2015).[2] While this includes military drones as large as aeroplanes, the proliferation of relatively cheap commercial models is democratising use of the "aerial commons" or grey-zone of mostly Class G lower airspace Garrett and Anderson call the "Nephosphere" (2018). Theoretical work has identified technological and material qualities and capacities of drones that are crucial to understanding how they complicate conventional airspace. Although they have limits in terms of range, payload, and so on, commercial drones are often seen as small and nimble compared with other aircraft, and are not easily detected or controlled, with the potential of going everywhere and being anywhere (Shaw, 2017). For Garrett and Anderson (2018), the blended capacities of flying and sensing are central, augmenting humans' experiential and affective abilities to see and know – and therefore operationalise – volumetric space. Klauser and Pedrozo (2015) too put visualisation combined with remote and flexible aerial mobility at the heart of drones' unique affordances, enabling new ways of seeing, monitoring, and exercising power over space "in, from and through the air" (p. 288). Importantly, they argue that drones constitute new air–ground relations, as a novel form of aeromobility capable of forging new connections through (air)space. Conceptualised this way, and especially as payload capacities grow, drone ecosystems come to bear distinctly infrastructural qualities for exploiting volumetric space as a useable resource – for aerial logistics networks, land mapping, emergency services, recreation, surveillance, crop spraying, and so on.

Much of the critical literature has focused on surveillance and racialised violence in relation to security-orientated drones, as a continuation of the use of airpower to control territory and populations (e.g., Akhter, 2019; Graham, 2016). However, as domestic airspace becomes more accessible to non-state actors, drone futures are increasingly seen as multiple rather than singular (Garrett & Anderson, 2018; Kaplan, 2020). Attention is turning to how technologies of military origin can be remade for diverse purposes and to generate social benefits and productive value. This has spurred booming investment and market activity in commercial drone services and systems, including numerous drone delivery experiments (Cohn et al., 2017; PwC, 2016). Yet public acceptance cannot be assumed with respect to concerns about surveillance, privacy, and air traffic, and drone flight paths raise questions about lower airspace property regimes and rights (Rao et al., 2016; Rule, 2015). Drones also raise prospects of airspace activities governments view as unwanted or "rogue," which may be dangerous (to people, infrastructure, and other aircraft), politically subversive, criminal, or violent (e.g., Clarke & Bennett Moses, 2014; Graham, 2016; Jensen, 2016). As airborne drones become more pervasive, they disturb airspace hierarchies, materialising increasingly complex risks and anxieties for state authorities and civilian populations alike (Klauser & Pedrozo, 2015; Shaw, 2017). The existing regulation of the skies usually allows for police and military drone operations, but for governments intent on facilitating the growth of certain drone services and markets, the challenge is how to manage negative impacts on airspace security, safety, congestion, and privacy.

2.2 | Reregulating airspace in the age of drones

The question of how tensions over access to airspace are reconciled is an inherently political one, through which the state (and particular branches within it) exercises hierarchical control over airspace, privileging or excluding certain interests. This will be central to determining what kinds of aerial infrastructures are materialised, and to whose benefit. Prevailing modes of airspace reregulation are driven by two crucial logics of enclosure, which are not straightforward to reconcile. The first logic of airspace enclosure is one of development and accumulation, where low-level airspace is constructed as an unused or under-utilised resource, for which there is an economic imperative of "improvement" (e.g., Goldstein, 2013; Li, 2007). As with conventional airspace, dronespace could be extremely valuable, but the "development of the sky" by drone capital and other interests requires the creation and enforcement of exclusive ownership, access, and use rights, which order, segment, and render it legible as a resource for experimentation, exploitation, and monetisation (Crampton, 2016, p. 138; Shaw, 2017). However, as Shaw (2017) argues, airspace enclosure is not only a moment of commodification, but a protective process of spatial and socio-technical "immunization," through which the state moves to secure, control, and purify its territorial atmospheres of unwanted objects. This second logic of airspace enclosure constructs dronespace as potential threat. This tends to dominate the historically risk-averse and securitised imperatives of airspace regulation, where capacity to distinguish between and control "safe" and "rogue" drones is the overriding consideration.

Although logics of dronespace development and immunisation are mutually constitutive, they are also often in tension. Regulation must try to resolve competing objectives and interests, through various spatial orderings, technologies, and rules governing acceptable traffic volume, density, and distribution of permits and rights. An open access vision could apportion equal airspace rights to all drone uses and users, perhaps with regulatory constraints on monopoly control. But the question is then how to secure lower airspace against rogue or unsafe drones. Increasing volumes of drone activity strain regulatory capacities and ATC would need to "simultaneously handle aircraft with onboard pilots, remote pilots, pilots with reduced training, and fully automated pilots … [and] variability in flight proficiency and communications medium (verbal vs. digital)" (Vascik et al., 2018, p. 4). It is important to note too, the distinction in air–ground spatial relations between drone delivery, involving flights from one point to another, and drone surveillance or mapping operations, which typically take off and land from a single site. While drones' heterogeneity and flexibility will blur these boundaries and infrastructural requirements, these different functions create different challenges in terms of configuring airspace(s) for drones.

The opening up of dronespace is therefore likely to involve new subdivisions of airspace for different uses. For example, Amazon made headlines with early lobbying to designate a layer of national airspace in the USA exclusively for high-speed delivery drones (BBC, 2015). Indeed, many real-world drone delivery experiments have been conducted in specially permitted drone corridors, which resemble the logic of helicopter travel in congested areas. Though expensive and relatively easy to identify, track, and control in comparison with drones, helicopters also tend to operate in lower airspace, and have generally been managed by creating designated corridors, routed to avoid commercial flight paths and populated areas where possible (Cwerner, 2006). Numerous other topographical options and technological solutions are also being designed and modelled to accommodate different scenarios and volumes of traffic for future dronespace. As part of the "Metropolis Project," for instance, Sunil et al. (2015) have simulated novel ways of organising airspace into "layers," "zones," and "tubes," to analyse the limits and trade-offs associated with increasing levels of structure and segmentation.

The risk of rogue drones can be managed to some extent through technologies such as "detect and avoid" systems, geofencing, and UAV Traffic Management (UTM) platforms, which can track and maintain control of an increasingly congested airspace (e.g., Federal Aviation Authority & NextGEN, 2018; Tomasello & Ducci, 2016). However, these technologies and various "technological counter-measures" designed to mitigate risk are not fully developed and reliable (Jackman, 2019). Regulation is therefore seen as all the more important. Codified rules, standards, permits, and protocols are used to police legitimate drone use. Numerous governments have sought to restrict commercial drones through stringent licensing and certification regimes, and banning specific classes and uses of drones (Hodgkinson & Johnston, 2018). To date, this has had a particularly constraining effect on commercial and civilian drones, especially those focused on delivery, although there have been a growing number of experimental programmes around the world. Many of these have emerged in certain African countries, which have become internationally celebrated sites of drone innovation, and where navigation of airspace regulation has been an important part of the story.

2.3 | African drone experiments

The emergence of real-world drone testing in the global south has been advanced by the rise of so-called "humanitarian drones." This term was coined to describe the growing use of small commercial drones to support emergency relief efforts in the aftermath of natural disasters in the early 2010s, most prominently in Haiti following the 2012 earthquake (Martini et al., 2016; Sandvik & Lohne, 2014). Since then, more programmatic "drones for good" initiatives have proliferated in the global south, which have proffered the potential for "high social impact" of drone applications across humanitarian work, healthcare provision, and economic development (USAID, 2017). The proliferation of this kind of drone testing has been particularly notable in many African nations (African Union, & NEPAD, 2018; Knoblauch et al., 2019). African drone innovation has been driven by a range of interests including global health and philanthropic organisations (including VillageReach, the Gates Foundation, and John Snow Institute), international development and donor agencies (especially

UNICEF, the World Bank, and several national aid agencies), smaller NGOs (such as WeRobotics, Drone Adventures and Humanitarian OpenStreetMaps), drone technology companies, logistics firms (including UPS and DHL), and venture capital funds, in partnership with national governments. While mapping and surveillance applications have been more common, donor finance has enabled a range of medical delivery experiments, usually facilitated by *ad hoc* negotiation of special permits (USAID, 2017).

These projects are often constructed as distinctly African opportunities, where drones are positioned as an ideal technology for modernising, integrating, and "leapfrogging" the continent's fragmented infrastructural landscapes, particularly between urban and remote, rural communities (African Union, & NEPAD, 2018; Sandvik, 2015). One form this takes is the representation of African airspace as an under-utilised resource ripe for development in the fight against poverty (Ledgard, 2014; see also Li, 2007), and a context where drone companies can "test their prototypes and perfect their technology in field conditions and in countries where regulations are more favourable" (Soesilo et al., 2016, p. 18). Numerous start-ups from the global north have moved into this space, including Zipline, Matternet, and Volansi (USA), Wingcopter (Germany), SenseFly and RigiTech (Switzerland), Wingtra, FlyPulse, and GLOBHE (Sweden), Swoop Aero (Australia), and TerraDrone (Japan). As Sandvik and Lohne (2014) argue, a strong commercial logic underpins humanitarian drone testing, with the industry seeking to ethically rebrand itself and diversify into new markets. While these kinds of drone initiative have unproven benefits for local communities, they often continue the long-running trend of seeing "African" developmental problems as solvable through technological innovation, and the colonial treatment of Africa as "living laboratory" (Kleine & Unwin, 2009; Tilley, 2011).

There is an emerging literature problematising humanitarian drone discourse and practices, highlighting how such initiatives extend forms of (neo)colonial surveillance and governance, and militaristic and technocratic "ways of seeing" (e.g., Sandvik & Lohne, 2014; Peckham & Sinha, 2019). These critiques make important interventions, but our interest here is how humanitarian and "drones for good" experiments are being enabled or constrained, and why they are landing in specific contexts. Mapping drone activity across the continent, Nzaramba et al. (2017) point to a number of factors at play, which is facilitating sites of African drone use. Their "drone readiness index" includes regulations, social and technical infrastructure, investment opportunities, existing drone use and experience, as well as prospects for social and economic impact in particular domains, to which we would add the political interests driving projects forward. As discussed at the start of this section, the legacies of colonialism have long undermined the development of African aviation, and lack of resources for regulatory and infrastructural airspace capacities remain a generalised constraint. African CAAs are governed by ICAO standards, but global inequalities limit their influence within the organisation. In their joint report on drone potential, the African Union, & NEPAD (2018) note that the standardisation of restrictive drone regulations, translated from ICAO guidance and being adopted throughout the continent, risks hindering the industry's development. Yet experiments have emerged nonetheless, with African countries becoming testbeds not just for technologies, but for drone regulation "in the making," including the use of drone corridors (African Union & NEPAD, 2018, p. 20; see also Knoblauch et al., 2019; USAID, 2017).

3 | REGULATING AFRICAN DRONESPACES: THE CASES OF TANZANIA AND RWANDA

3.1 | Tanzania: contested reregulation and closing down of airspace

Since the mid-2010s, Tanzania has become one of the most celebrated sites of drone innovation in Africa, with notable projects including the digital mapping of Zanzibar and the Lake Victoria Challenge drone expo. However, since 2017, the Tanzania Civil Aviation Authority (TCAA) has moved to extend its control over commercial drone activities. Despite considerable lobbying by domestically operating drone interests, new regulations that came into force in December 2019 brought Tanzania in line with the international tendency towards heavily restrictive drone rules.

Tanzania has seen considerable economic liberalisation since it was compelled to implement a World Bank structural adjustment programme in the 1980s, but governance is often still understood through the lens of the developmental state associated with founding president Julius Nyerere (Gray, 2013). Yet despite uninterrupted rule of the Chama Cha Mapinduzi (CCM) party and its predecessor since independence and unification of Tanganyika and Zanzibar in 1964, political power is less centralised than commonly assumed. State power has traditionally been distributed between different factions of the CCM across government (Gray, 2013), while Zanzibar's semi-autonomous status complicates notions of strong hierarchical control (see Eriksen, 2018). Although the TCAA operates under ICAO standards, technical capacity to control national airspace is limited. This is partly a product of the late colonial period, when civil aviation was administered regionally across British East Africa, which continued after independence. Tanzania was part of a post-colonial East African airspace regulation network until 1977, with area control only established in Dar es Salaam in 1998. By 2018 TCAA had only one radar station covering just 25 percent of its airspace, paying neighbouring Kenya for surveillance services to monitor the rest of Tanzania's expansive territory (All East Africa, 2018; TCAA, n.d.).

Unregulated drone use was first recognised as an issue in Tanzania in the early 2010s. As a security measure against poachers, national parks were the first areas designated no-fly-zones for drones in 2014. However, until 2017 there were no standardised drone-specific permitting procedures. Interventions were made by TCAA on a reactive case-by-case basis, often after authorisation from another branch of government. Under conditions of dispersed authority and regulatory ambiguity, nascent drone experiments and drone-related interests coalesced around a development-oriented "drones for good" narrative (e.g., Ackerman & Koziol, 2019). This network included domestic start-up operators, NGOs (e.g., WeRobotics, Humanitarian OpenStreetMap, Drone Adventures), and universities, along with large donor organisations, foreign drone companies and officials within branches of national and subnational government, such as Lands, Health, and the Commission for Science and Technology (COSTECH). Crucially, the World Bank's Tanzania office took a special interest in drones as a technology and lower airspace as an undeveloped resource, which could potentially leapfrog infrastructure constraints on economic development and poverty reduction. It took a leading role supporting drone experiments, and aligning donors, drone operators, and government interests, with particular focus on land mapping and developing cargo delivery to remote communities.

Early applications mainly involved mapping and monitoring groundspace, including disaster response and several projects mapping land for territorial administration and planning (see African Union & NEPAD, 2018). Although there was an outside perception that "lack of regulation" meant a permissive environment for drone testing in Tanzania, the reality was quite different. Mapping projects in Dar es Salaam and Zanzibar exemplified the political work required to cut through a complex regulatory landscape. One World Bank official explained how on the mainland, they began with a COSTECH research permit which mixed different agendas, enabling them to carefully enrol TCAA, MoD, local government, and the Ministry of Lands and avoid potential turf wars and obstacles put up by competing branches of government. The larger scale Zanzibar Mapping Initiative (ZMI),[3] which began in 2016 and became one of the most celebrated sites of African drone innovation, was able to flourish in large part because of government support in semi-autonomous Zanzibar. Built on the foundations of a geospatial data programme at the State University of Zanzibar, which had been funded by Statoil (now Equinor), ZMI started as a small-scale mapping experiment of the centre of Zanzibar City for urban planning, facilitated and part-financed by the World Bank. Led by the Zanzibar Commission for Lands (COLA) and World Bank, this pilot project gradually expanded, eventually mapping the entire 900 square miles of the archipelago, at one-tenth of the $2.5m cost of the 2004 survey using conventional aircraft and volunteer student labour. ZMI was strongly supported by the Government of Zanzibar, with the prospect of high-quality, up-to-date spatial data serving strategic and political interests in land administration, development control, taxation, and resilience planning, and opening up potentially lucrative offshore natural gas reserves.

Within uncontrolled airspace, the Zanzibari authorities were initially able to approve most flights without recourse to TCAA. Nevertheless, as ZMI expanded, proposed drone operations unavoidably moved into controlled airspaces, requiring additional authorisation from mainland regulators and ATC. To gain the necessary permits, regulators, state security apparatus, and other national agencies had to be convinced that operations would meet the strictest airspace standards, especially in relation to air traffic and military zones. One official explained how this was achieved:

> It may be that there's no *written* regulation when it comes to drones, but there's a[n existing] protocol for aerial photos. … So, we convinced the government we'll use the same protocol. You ask permission, and you talk with security and they tell you about sensitive areas. You avoid showing those sensitive areas. Then you inform the local government … [and local] people. … We have to go to the [airport] control tower … to make sure we avoid confusion and accidents. … Whenever we talk with them, we just make sure that their concerns are addressed. (COLA official)

Following this protocol, ZMI obtained permits that enabled blocks of airspace to be temporarily activated, facilitating over 3,000 pre-planned flights, carried out using small, hand-launched SenseFly eBee survey drones, where VLOS monitoring was maintained at all times. Having carefully navigated and enrolled government interests and regulators at different moments, ZMI was able to complete this work, even after stricter drone-specific rules were introduced.

3.2 | New regulations: extending centralised control over dronespace

As experimental projects proliferated, concerns about airspace safety risks led to the introduction of new regulations in January 2017, through the Aeronautical Information Circular (AIC) for Unmanned Aircraft Systems (TCAA, 2017). Following provisional ICAO (2011) guidance, AIC 5/18 made drones subject to the stringent regulations, standards, and operational restrictions of civil aviation. As well as requirements for pilots and drones to be registered and certified, it contained authorisation and notification procedures separately administered by TCAA, Ministry of Defence (MoD), and other relevant bodies – such as airport authorities, ATC, local government, customs, and the meteorological agencies. TCAA were particularly concerned about capacity to manage more complex beyond visual line of sight (BVLOS) delivery services, with ideas circulating for commercial corridors and droneports, apparent interest from Google's Project Wing, and more serious (but ultimately abandoned) proposals for a government-funded medical delivery network operated by US start-up Zipline (see McNabb, 2017). Autonomous flying was restricted to specially permitted government operations and BVLOS flying was proscribed without exceptional permission from TCAA. Drones could not fly above 400 ft, over populous areas, or within 5 or 3 km of international and domestic airports. Onsite MoD accompaniment became a stipulation for commercial operations, and a government directive later required operators to be vetted by the intelligence services. In mid-2018, the Ministry of Works, Transport and Communication (under which TCAA operates) published draft legislation, which would bring domestic drone activity more comprehensively under TCAA control.

After AIC 5/18 was published, experimental and commercial activity became increasingly constrained. Many within the drone network recognised the need for a regulatory framework to mitigate airspace risks, but that would also render it legible and accessible to market actors. However, they favoured fast adoption of tracking and UTM systems as the solution to regulatory anxieties, which could "help the good guys" while enabling more flexible airspace use. Operators complained that the new process remained overly restrictive, costly, and opaque, and permits were constantly delayed by bureaucratic problems and struggles between state authorities. One operator explained how he still relied on:

> Connections I've built rather than transparency of the process. … What's the future of drones in Tanzania? Unless we get our shit together, nothing! To put that in context, I've spent about $50,000 on professional survey-grade drone equipment, about nine months ago, but it hasn't paid for itself yet. I should have two sets by now. … Tomorrow the state could turn around and say no more drones in Tanzania, which turns that $50k into a dead investment. (Domestic drone operator)

TCAA officials strongly rejected criticism, arguing they supported beneficial projects if standards were met. They pointed to their role facilitating the complex six-month trial of medical deliveries with German company Wingcopter in 2018, led by the Ministry of Health and others between facilities in the city of Mwanza and Ukerewe Island on Lake Victoria, which established Tanzania's first temporary drone corridor. However, they maintained that the cautious nature and pace of regulatory development was necessary, reflecting their overriding legal duties to airspace safety and security under constraints of limited capacity. For TCAA representatives, the frustration exhibited by parts of the drone network – and some foreign organisations in particular – suggested a reckless and "selfish" disregard for their authority over sovereign airspace and long-established aviation protocols (Interview with TCAA regulators).

During this period of contested reregulation, more purposeful attempts were made to cajole regulators into a more flexible approach, using the inaugural Lake Victoria Challenge (LVC) as a dronespace living lab. Bringing together 280 people, including government policymakers, regulators, consultants, ICAO officials, technology firms, and major donor agencies, this three-day international expo took place in the city of Mwanza in October 2018 to showcase drone innovation and opportunities in Africa (Wakefield, 2019). Led by the World Bank, it was designed to demonstrate the potential for connecting fragmented economic activity, services, and communities using cargo-carrying drones as a form of "aerial infrastructure." Lake Victoria and the Mwanza region were chosen as a "laboratory for real-world testing,"[4] where lack of safe and efficient transportation between urban and remote rural and island communities was presented as particularly acute, but also typical of infrastructural challenges faced across Africa.

LVC hosted five drone manufacturers and four UTM companies,[5] airspace regulators from nine African countries, and countless other stakeholders. The practical "challenge" for participating teams was to demonstrate drone technologies flying BVLOS through a 22-km corridor between the city and island of Juma over open water, including safe take-off and landing, across a complex mix of civilian and military airspace, monitored by ATC. This required a special permit authorised by TCAA, MoD, ATC, and other agencies. LVC pushed the limits of Tanzania's regulations, but the hope was that by making the event symbolically "too big to fail," regulators would be pressured to cooperate rather than obstruct the process. Obtaining the permit to stage LVC at all was considered a success. Most importantly, it created an opportunity to familiarise regulators with the latest drone and UTM technologies, and demonstrate how a safe and secure corridor infrastructure for high-volume drone traffic could be assembled.

Yet TCAA representatives were relatively unmoved by what they saw and the calls for a more flexible attitude. Pointing to continuing concerns over BVLOS and autonomous flying, they argued that drone operators' lack of training and familiarity with airspace rules and language meant few of them "understand aviation." In some ways, LVC even entrenched their views that influential drone interests saw regulation as an impediment to their projects rather than a necessity. The new regulations were published six weeks later (TCAA, 2018). New requirements, which came into force 12 months later, included regularly renewed operator certification and pilot licence schemes overseen centrally by TCAA, with operators expected to be trained to the rigorous standards of civil aviation protocols, together with stringent security vetting procedures. Additional communication and surveillance protocols and technologies are specified, and the regulations stipulate numerous circumstances where exceptional approvals must be sought from TCAA, ATC, and airport authorities.

The new rules represented a considerable extension of TCAA control over all aspects of domestic drone activity. The more restrictive environment already appears to have had an effect. A second, more expansive LVC was planned for December 2019, before an announcement in September that a renamed African Drone Forum and Lake Kivu Challenge would instead take place in Rwanda in February 2020. According to an LVC newsletter, the decision was based on the more flexible approach taken by the Rwandan government, as the "first in Africa … to promulgate comprehensive performance-based UAS regulations allowing Beyond Visual Line of Sight (BVLOS) commercial operations." The paper now turns to Rwanda, where the reregulation of airspace for drones is increasingly held up as an exemplar framework for facilitating drone development.

3.3 | Blood flows: the development state and drone facilitation in Rwanda

In 2019 Rwanda had the world's most extensive drone delivery network, and arguably one of the most sophisticated regulatory frameworks for facilitating drone operations. Designed and operated by US start-up Zipline, drones deliver blood and other medical products from two droneports to facilities across the country via designated flight-path corridors.

Located in central Africa with a population of 12 million, the strong social and spatial control exerted by the Paul Kagame government's security apparatus offers very limited scope for unregulated drone use (Reyntjens, 2013). Drones must be registered with the Rwandan Civil Aviation Authority (RCAA) and cannot be imported without a licence. Drones flying without authorisation from ATC, military agencies, and local police are liable to be shot down. Drawing on ICAO guidance, regulations introduced in 2016 reiterated the presumption against unregulated drone use, but also sought to facilitate growing demand for commercial services for land mapping, conservation, agriculture, and infrastructure maintenance (RCAA, n.d.). Under the regulations, drones were limited to 25 kg, were prohibited within 10 km of any airfield, or within 50 m of people, buildings, vehicles, ships, and animals. Flights were restricted to VLOS up to 300 m. Permits could be granted for single operations in a specific area, or for a group of activities for up to a year. Additional permits might be needed from the Rwanda National Police or Rwanda Defence Force for aerial photography and/or overflight of security-sensitive locations. Local authorities, police, and landowners had to be notified of any flight plans.

The 2016 regulations mirrored the international trend, but were superseded in 2018 by the Regulations Related to Unmanned Civil Aircraft Systems, representing an important shift (RCAA, 2018). The updated regulations maintain registration requirements (although "toys" became exempt), but permit 50 kg drones and speeds up to 100 mph, and allow for exceptional permission to fly in prohibited and restricted areas. Most significantly, they established a framework for enabling commercial BVLOS flights if: (1) the operation is approved by ATC; (2) drones have appropriate "Detect and Avoid" technology and capacity to respond to changing weather conditions; (3) flights are operated from established aerodromes, droneports, or locations meeting specified standards; and (4) direct telephone communication is maintained between pilots and ATC. In addition, "highly automated UAS operations" were made possible with high-level authorisation from the National Civil Aviation Security Committee.

3.4 | Zipline and the 2018 BVLOS regulations

The Rwandan government has become strongly supportive of drone development, as part of a broader political commitment to become an international leader in technological innovation for social and humanitarian progress. This agenda has been central to a wider strategy, as articulated through Vision 2020 and subsequent programmes for economic development, poverty reduction, and internal stability under Kagame's Rwandan Patriotic Front, which has overseen the country's economic recovery since the 1994 genocide (Behuria & Goodfellow, 2019). The introduction of "flexible" drone regulations and plans for a Drone Operations Centre to develop domestic expertise have been critical in Rwanda's growing reputation for drone innovation and public–private partnerships (Mwai, 2018) – and as a continental hub for ICT, financial services, and logistics.

Regulation has also been developed in response to the requirements of drone operators, notably the Silicon Valley company Zipline. Founded in 2011, Zipline has built its reputation as a developer of "life-saving" logistics systems in Africa using drones, with the backing of major investors including venture capital funds, the Gates and UPS foundations, the Gavi Alliance, and Pfizer. Zipline's blood delivery system in Rwanda has its origins in a proposal from Jonathan Ledgard, former African correspondent for *The Economist*. Ledgard's (2014) idea was to exploit under-utilised lower airspace with flight paths for "blueline" (commercial) and "redline" (humanitarian) delivery networks, and initially included ambitious plans for futuristic droneports designed by Norman Foster. Unlike others with similar proposals, Ledgard had access to President Kagame, and the Rwandan government agreed to fund 33 percent of the costs, worth US$2.2m. However, difficulties in raising the other two-thirds meant the Redline project stalled (Interview with national development agency official). When Redline failed to generate investment, Zipline approached the Rwandan government through Ledgard, leading to a three-month trial and initial one-year contract in 2016, which has since been extended. Zipline's commercial operation is now funded by the Rwandan government with payments for delivery to a set contract. Rwanda already had an established network of blood transfusion facilities (linked by roads) that showcased the country's developmental aspirations. Drones had particular symbolic value and appeal in enhancing this existing infrastructure by reducing costs, delivery times, and blood wastage, while extending its reach, especially in remote mountainous areas.

Zipline's system uses purpose-built fixed-wing drones launched by slingshot from one of two droneports. The drones do not land, but drop parachuted packages from the air to delivery sites, before returning to their launch sites to be caught by zip wire. Mainly carrying blood products and other lightweight medical supplies, the drones are powered electrically, and are light enough to fly for 100 minutes. Zipline Rwanda started with one launch site in Ruhanga covering the west of the country. A second was established for the east in 2019. Operations rely too on the telecommunications network, with just-in-time orders made using WhatsApp, email, or phone. All drones are tracked and monitored by RCAA, and there is a control tower at the launch site, though automated systems make this mostly redundant. Zipline's system largely uses off-the-shelf technology, such as iPads, apps, commercially available sensors, and ultra-light Styrofoam bodies. Heavier payloads are possible, but range would be restricted, and accident risks greater. Drones that could take off and land would also be useful for collecting blood test samples, but would require managed landing sites and further personnel training. Drone deliveries "did not result in a major shift in the system of blood supply," but largely supplemented it (Interview with national medical agency official). Although intended to save transportation costs, Zipline's system has proven more expensive than the road-based system. Its primary benefit has been a reduction in wastage of stored blood products (especially important in more remote facilities) from 6 to 0.3 percent, enabled by Zipline's just-in-time system and access to exclusive air routes.

The overriding challenge for the project was developing an appropriate framework for airspace regulation. Central government support and steer was essential. Airspace regulators were tasked with finding a suitable configuration of airspace rules, designations, and protocols compliant with ICAO standards while meeting government objectives. Initially this meant classifying Zipline drones as state aircraft, and over time the creation of a system of highly structured, enclosed corridors, with the main flight paths branching off to more remote areas. Road crossings and population centres are avoided where possible. Flights are monitored and contact maintained with ATC, but close coordination with RCAA has permitted Zipline to gradually operate more autonomously. The whole project is coordinated by a high-level steering group of key government interests, including the Ministry of ICT and Technology, military and security agencies, the Rwanda Development Bank, and the National Commission of Research and Technology, which reports to the President's Office. As one Zipline representative explained, planning and permission would have taken five to ten years in most countries but took less than two years in Rwanda because of the coordinated approach.

Innovations in drone infrastructure and regulation in Rwanda reflected the modalities and interests of the governmental regime. Its ability to effectively establish protected corridors through domestic airspace while maintaining tight control over drone use outside those zones has been crucial. Upfront infrastructure investment underwritten by government funding has been equally important, as have unified efforts to advance blood transfusion as a national development project. Though supported and boostered as "revolutionary" by the World Economic Forum (2018), the permissive nature of the performance-based regulations should not be overstated. Rwanda has been far from an open testing ground for drone companies from the global north. Other drone interests, including Toyota, Wingcopter, and Airbus, have sought to enter Rwanda, but to date there have been no commercial ventures to match Zipline's success (Interview with national development agency official).

The opening of dronespace in Rwanda can be a lengthy, incremental process in which drone operators have to gain the trust of RCAA regulators, through extensive engagement. Nevertheless, commercial operators felt this to be an appropriate approach, in requiring high airspace standards, and suggested the absence of corridor networks similar to Zipline's reflected the complexities of commercial drone logistics as much as constraints imposed by regulators. In this respect, Zipline's upfront investment was partially de-risked by generous government contracts. Existing infrastructure was already in place with defined drop-off points, and the system had some benefits for relatively light but high-value cargo.

Despite the contingent circumstances, Zipline Rwanda has demonstrated the potential for an infrastructural solution that reconciles competing logics of dronespace enclosure and helps overcome the concerns of risk-averse regulators. This could and is being replicated in different institutional contexts, presenting significant opportunities for Zipline to capture new markets – leading to major investment in 2019, taking the company's value to US$1.2bn (McNabb, 2019). While its proposals in Tanzania ran aground, Zipline began a US$2m four-year contract in Ghana in 2019, to operate 30 drones from four sites "to distribute vaccines, blood and life-saving medications to 2,000 health facilities" serving 12 million people, which CEO Keller Rinaudo said would be "the largest drone delivery network on the planet" (Bright, 2019, n.p.).

4 | DISCUSSION: THE POLITICS OF DRONE REGULATION

Around the world, governments are wrestling with the dilemma of how best to reregulate airspace to control and selectively facilitate commercial drone activity. Dronespace appears at once as a tantalising frontier for exploitation and a significant risk to public safety and security, where the rapid development and proliferation of drone technology continues to outpace existing mechanisms of control (Garrett & Anderson, 2018; Jackman, 2019; Shaw, 2017). Although many aspects of flight are now automated in conventional aircraft, autonomous flying drones pose challenges to the prevailing logic of situated human vision and override. As cheap drones and experimental applications spread into new areas, airspace regulators are being asked to navigate and reconcile these growing tensions. As the examples of Tanzania and Rwanda reveal, there is variation in regulatory responses, embedded in local contexts and ensembles of interests driving drone development. Nevertheless, the extension of centralised state control over dronespace in line with conventional airspace standards is the dominant story in both cases, suggesting powerful limits to the disruptive and democratising potential of drones.

In Tanzania, drone experimentation was initially able to proceed in a context of ambiguous regulatory authority. Led by the World Bank and particular branches of government, and funded largely by donor finance, various mapping projects established Tanzania as an early centre of African drone innovation. However, anxieties about safety and security, especially in relation to BVLOS and autonomous delivery services, led to a regulatory closing down of dronespaces. The nascent drone network in Tanzania was unable to allay regulators' concerns or cohere a strong enough countervailing set of interests to force a more flexible approach or support for corridor infrastructure from TCAA, which extended its control over domestic drone activity. In Rwanda, drone ownership is tightly controlled and there are strict protocols for registered drone operations. The landmark drone corridor network for delivery of blood and other medical products developed with Zipline has led to some of the most advanced and permissive regulations for semi-autonomous and BVLOS operations in the world, albeit still subject to tight regulatory control. Zipline's success in establishing a commercial delivery network in Rwanda has been heavily contingent on the government leadership's political and financial embrace of medical delivery drones as a national development project. Through this, the company was able to demonstrate the reliability of its infrastructural approach and systems, and cement its monopolistic position as a trusted service provider, attracting additional private flows of capital investment. Yet this took place under relatively unique conditions, where comprehensive ground and airspace control by the state security apparatus was a necessary prerequisite for the development of dronespace.

The case studies have important implications for literature on airspace regulation in the age of drones. First, our findings refute Eurocentric notions of Africa as an unregulated testbed for drone experimentation (Sandvik, 2015; USAID, 2017). Although clearly structured by the legacies of colonial rule and logics of post-colonial development, African modes of airspace regulation are no less stringent than in other parts of the world, and commercial drone use is tightly regulated in line with ICAO standards. Governments in Tanzania and Rwanda have maintained and extended regulatory control, and airspace sovereignty was unquestioned. The narrative of unregulated drone use in Tanzania before 2017 was never accurate. The discourse in Rwanda has been about creating space for innovation in drone systems and delivery networks in particular. Yet while the country's performance-based regulations have received plaudits for their flexibility by organisations like the World Economic Forum (WEF) (2018), they are underpinned by uncontested governmental control over domestic drone activity. Zipline's delivery network has been subject to strict oversight, developed through careful and incremental changes to airspace regulation, requiring strong, coordinated intervention and proactive enrolment of RCAA, to resolve competing demands. What has been more important than permissive regulation in the spread of drone testing in Africa is the ensemble of political interests (including crucial branches of the state) able to navigate regulatory constraints and drive projects forward. However, experiments with drone corridors in Tanzania and other countries have not translated into extensive commercial drone infrastructure networks. One of the more distinct issues in the African cases is that while entry costs for drone mapping services might be fairly low, delivery services remain largely experimental due to the level of upfront investment required in the drone ecosystem.

Second, our examples demonstrate the distinction between drone services that are limited to specific blocks of airspace for surveillance, mapping, crop spraying, and so on, and cargo services that connect logistics hubs to delivery locations. Different services may require different forms of regulation and relationships between drones and infrastructure on the ground. The temporary activation of blocks of uncontrolled lower airspace for mapping operations appears more straightforward to manage with licensing, permits, and VLOS monitoring, and potentially offers significant cost savings for certain services. The question for BVLOS drone delivery, however, is how to create a more permanent infrastructural approach that can manage more regular traffic flying semi-autonomously between different locations, while meeting strict standards of airspace safety and security. This model suggests a process of slow evolution and reproduction of existing modes of airspace regulation, and the political question of who and what is granted airspace rights – and where – comes to the fore. Control over delivery routes will shape choices about what goods and services are delivered and to whom. Decisions about what happens in the air will have social, economic and environmental impacts on the ground, and are likely to become key sites of political contestation with respect to drone infrastructuralisation. The Zipline system in Rwanda (and now Ghana) is one way of creating an infrastructure of selective airspace enclosure, which could resolve competing demands. The creation of designated corridors enables willing governments and regulators to take more calculated risks in testing and developing drone delivery systems and technologies, moving beyond the regulation of individual drone operations *per se*, while maintaining strong hierarchical control.

Zipline's networked corridor logic connecting major centres of population with branch lines to other delivery sites is currently restricted to medical use but could be extended to other types of drones and commercial delivery services. Developing this infrastructural capacity would require significant long-term financial investment in physical assets, monitoring systems, and regulation, including droneports, detect-and-avoid and UTM systems, corridors, and autonomous flight protocols for safely integrating drones into conventional airspace. Although many governments are keen to develop drone infrastructure and providers are eager to supply it, the risks are high and revenues uncertain. Commercial investment tends to focus on higher return markets rather than low- and middle-income countries and international donors have largely funded "boutique pilot projects" rather than longer term investment in infrastructure systems (Defawe & Sarley, 2020). Zipline's operation in Rwanda is somewhat exceptional in its ability to absorb the high costs of investment because of generous government contracts, but its operation in Ghana proved controversial for the same reason, with detractors arguing resources could be more productively invested elsewhere in the healthcare system, such as new ambulances (Murray, 2019). While drone corridors could potentially allow for multiple commercial users, it is difficult to identify the logic through which an open democratised infrastructural resource could develop. Current models are based on infrastructure solutions that enclose and grant exclusive rights and access to privileged interests in return for investment. Additionally, the social benefits of health-related just-in-time drone delivery do not necessarily translate to a business case that depends on reliable, high-volume traffic to achieve economies of scale. Furthermore investment in premium drone corridors serving large, well-connected populations is likely to prove more attractive than extending health services to more remote or unprofitable communities. Our findings challenge claims that drone experiments will offer an inherently democratising form of aeromobility and unlimited connectivity.

5 | CONCLUSION

In this paper we have sought to extend geographical and wider literature on the emerging spatialities of drones by examining how governments and airspace regulators in Tanzania and Rwanda have responded to the challenge of selectively facilitating commercial and civilian drone operations. These case studies, we argue, provide important insights into the challenges of regulating airspace in the drone age and the future constitution of dronespace and corridor infrastructures in particular. Our research makes three major contributions to knowledge and understanding of airspace in the age of drones. First, our African case studies widen the scope of empirical work on drone geographies, adding nuance to debates predominantly drawing on European and North American contexts (Klauser & Pedrozo, 2015). Second, in demonstrating strong tendencies towards state control and risk-averse reregulation of airspace in both Tanzania and Rwanda, our findings challenge certain myths about African countries as un(der)regulated testbeds for foreign drone companies. Third, we add to broader debates about the constitution and enclosure of dronespace. We highlight the enabling role of corridor infrastructure in response to specific challenges surrounding delivery drones, which require a shift from established regimes of control based on human sightlines and in-flight human override to semi-autonomous or autonomous flying Beyond Visual Line of Sight, where control is operated at a distance. However, we suggest the costs of such systems are likely to constrain ownership, access to, and use of dronespace to relatively few licensed operators, restricting the degree to which drones are likely to democratise airspace as an infrastructural resource and form of aerial connection. This opens up new avenues for critical geographical research, all the more urgent as drone corridor testing takes off in other parts of the world – now being accelerated as a logistical response to the challenges of healthcare provision and protection in the context of the COVID-19 pandemic.

ACKNOWLEDGEMENTS

We are very grateful to the four reviewers whose generous but challenging comments greatly improved the paper and to Matt Sparke for his encouraging editorial steer. We would also like to extend our appreciation to all our extremely accommodating interviewees and in-country partners who helped facilitate our fieldwork, as well as our advisory board, and especially Tom Goodfellow and Jon Silver, whose constructive engagements over the course of the project were invaluable in shaping the research. Finally, we would like to thank our funders at the British Academy for making the research possible through grant KF1\100069 of the Knowledge Frontiers programme.

DATA AVAILABILITY STATEMENT

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

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ENDNOTES

[1] Fieldwork involved site visits and interviews carried out by three of the authors with 30 individuals in Tanzania and Rwanda, including private and non-profit drone operators, consultants, NGOs, donor agencies, government officials, and airspace regulators. Obtaining research permits and clearance was a lengthy and complex process, and ultimately proved impossible in a third country (Malawi) within the timeframe of the project. While there is not space to explore the methodological issues in full in this paper, a project report with further detail is available at [http://urbaninstitute.group.shef.ac.uk/wp-content/uploads/2021/04/DRONEFINAL-REPORT-MARCH-2019.pdf] (Accessed April 1, 2021)

[2] We use the term drones to refer only to aircraft here, though we acknowledge the growing number of 'underwater' drones being developed.

[3] See www.zanzibarmapping.org (Accessed March 2021).

[4] See https://www.africandroneforum.org/about/lvc-2018/ (Accessed March 2021).

[5] The drone manufacturers were FlyPulse (Sweden), Wingtra (Switzerland), Wingcopter (Germany), RigiTech (Switzerland), and Siniger (USA). The UTM companies were Exponent (Dubai), AirMap (USA), Unifly (Belgium), and Involi (Switzerland).

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How to cite this article: Lockhart A, While A, Marvin S, Kovacic M, Odendaal N, Alexander C. Making space for drones: The contested reregulation of airspace in Tanzania and Rwanda. *Trans Inst Br Geogr*. 2021;00:1–16. https://doi.org/10.1111/tran.12448