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ORIGINAL ARTICLE

# Drones and epidemiology: A new anatomy for surveillance

**Francisco Tirado**[1] · **Pedro Torrejón Cano**[1]

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**Abstract** This article analyses drones as an upcoming device in the field of epidemiology. It is based on a research project which aims to track the variations in the forms of vigilance experienced by epidemiology in recent decades. After surveying approaches such as bioepidemiology and tele-epidemiology, we propose that the use of drones in this discipline entails the onset of a new era for surveillance and control, which may transform the very articulation of our societies; this is because surveillance is no longer conducted to monitor, much less to punish, rather it now aspires to create and manage the global circulation flows that determine our behaviours in real time.

**Keywords** Drones · Bioepidemiology · Tele-epidemiology · Movement · Surveillance · Flows · Control

## Introduction

As a host of sociologists, historians, philosophers and political scientists have pointed out (M. Foucault, Z. Bauman, P. Bourdieu, M. Castells, among others), *surveillance* processes are an inherent part of what we call 'modern societies'. This does not mean that these practices did not exist in previous cultural structures, but simply that in ours they take on the task of making our everyday life intelligible and structuring them as they never have before. Today, the security of citizens and their infrastructures, interests and investments are regarded as a necessity to achieve a full, quality life (Lyon 2015). Of course, security also means surveillance. As Foucault (1994, 1995) has shown, this was, in turn, traditionally associated with a logic of punishment. The conduct of individuals and peoples was monitored, and

✉ Francisco Tirado
franciscojavier.tirado@uab.es

[1] Univesidad Autonoma de Barcelona, Bellaterra, Barcelona, Spain

differences were managed by meting out sanctions and penalties (particularly in the institutions where the everyday lives of those actors unfolded). However, this logic started to weaken in the latter half of the 20th century and seems to have been forcibly removed at the dawn of the 21st century (Ramonet 2016). Thus, during the second half of the 20th century, we witnessed a transformation in which surveillance ceased operating with the logic of punishment and was replaced by the logic of *control*. As Gilles Deleuze (1992) notes, in this new stage, surveillance is used to implement open and continuous dynamics of control through the use of elements such as psychotropic drugs, consumption, marketing and/or citizen indebtedness. In this mutation, we can see that not only is there a change in the strategies of interaction between surveillance and punishment, but there is also a metamorphosis in the very dynamics that constitute surveillance processes. What does it mean to perform surveillance in the 21st century? How can it be performed efficiently? What supervisory tools should be associated with surveillance to ensure that it does not hark back to punishment? These questions are the analytical keys that determine the recent historical transformation of the surveillance mechanisms that populate our day-to-day lives.

This article is based on an investigation that seeks to analyse the mutation detailed below, taking as its point of departure an area in the set of discourses and practices that characterise a very specific scientific discipline: epidemiology. Our interest stems from the fact that, as several authors have suggested (Canguilhem 2012; Foucault 1994; Rose 2007), since the 18th century, the field of medicine and health promotion has become a fundamental dimension in the shaping of the practices and discourses that characterise the modern day. Specifically, epidemiology crystallises better than any other biomedical discipline the tension generated by the simultaneous requirements of the biomedical and the social sciences, inasmuch as infectious and contagious diseases are a problem that involve society as a whole through procedures that extend beyond just medicine (Nishi 2015; Berkman et al. 2014; Tirado et al. 2015; Vibeke and Rodrigo 2004; Krieger 1994, 2000; Watts 1999; Rosenfield 1992).

Specifically, epidemiology plays an essential and leading role in the organisation and management of our societies, and is a discipline that directly reflects their surveillance mechanisms. In epidemiology, we observe the blending of distinct territorial scales (the city, the magistracy, the department, the state and the world) and a plurality of dimensions (medical, economic, scientific and political). In this respect, authors like Michel Foucault (1994) described the role of "epidemiological surveillance" in the constitution of European societies from the 18th century onwards as a crucial element in the constitution of the present day. Thus, in the 19th century, we saw epidemiological surveillance based mainly on the principles of statistical calculation, whereas, in the 20th century, we witnessed the rising of a surveillance of diseases based on preparedness criteria. Nowadays, however, we are witnessing the emergence and gradual consolidation of a molecular syndromic surveillance that redefines our classical conceptions of what societies, populations and individuals are. Hence, as a sphere of reflection and knowledge-production, epidemiology has placed itself at the intersection of the social problems, political requirements, medical knowledge and medical practices that govern our everyday

behaviour. In short, it has become a fertile ground to analyse the changes that characterise our present point in history.

In the following sections, we would like to analyse all such transformations based on a research project being carried out over the last 3 years at the Universitat Autònoma de Barcelona (Spain), the aim of which is to track the variations in the forms of vigilance experienced by epidemiology in recent decades. In it, numerous individual and group interviews with experts and non-experts have been conducted, audiovisual material has been gathered, several ethnographies have been made in centres involved in epidemiological activity and particular attention has been paid to recent investigations that see the use of drones as the central mechanism of the discipline's activity. More specifically, this paper stems from the analysis of public and open documents describing several research projects and initiatives using drones in epidemiology.

We shall begin by briefly surveying the classical types of surveillance in the field of epidemiology (focusing on statistical calculation). Subsequently, we shall survey the emergence of new devices such as "bioepidemiology" and "tele-epidemiology". Thirdly, we will assert that in recent years a new mechanism has suddenly and silently appeared in this field: the use of drones. We will demonstrate what drones are and analyse the implications of using them in the field of epidemiology. Finally, we shall propose that the emergence of this new technology entails the onset of a new format or anatomy for surveillance, which may transform the very articulation of our societies as a whole. Drones mean the articulation between bio and tele-epidemiology, the solution for the problems of both perspectives and the emergence of a new definition of control. This is because surveillance is no longer conducted to monitor, much less to punish, rather it now aspires to create and manage the global circulation flows that determine our behaviours in real time.

## Epidemiology and surveillance

The sudden importance of medicine in the 18th century is rooted in the intersection between a new analytical care economy and the emergence of a general health "police" (Foucault 1994). That is, in the 18th century, a social and technical network was established (spaces, regulations, norms, social conducts and measurement and evaluation instruments were created) that extended far beyond the medical-health dimension, whose epicentre became the focal point of the interferences and tensions emerging from epidemiology. In this sense, we should heed Michel Foucault's claim (1994, p. 47) that epidemics are something more than a particular form of disease: "there would be no medicine of epidemics if it wasn't reinforced by police: monitoring the location of mines and cemeteries; incinerating corpses as quickly as possible instead of burying them; controlling the trade of bread, wine, meat; regulating the slaughterhouses and the dyeworks; banning insalubrious accommodations".

Thus, it is no exaggeration to claim that the 18th century witnessed the gradual instatement of a "multiple surveillance network" that emerged, together with the instatement of the modern nation-state, and deemed that the health of the nation

should be actively, precisely monitored. This way, medicine began to expand its horizon of activity and regard fields far from mere pathology as its own. This transformation of its sphere of action took place with the following resources: (a) the appearance of a medical authority which was not merely an authority of knowledge but also a social authority that could make decisions affecting a city, a neighbourhood, an institution, a regulation, a village or a specific community; (b) the expansion of the sphere of medical intervention which now included air, water, construction, land and drainage; (c) the introduction of an apparatus of collective medicalisation—namely, the hospital—which ceased to be a place to care for the poor awaiting death and (d) the introduction of medical administration mechanisms, such as drawing up and comparing statistics (Foucault 1994).

The historical objective was to create a surveillance network grounded upon the idea of 'public hygiene' through comparative and statistical mechanisms. The inclusion of these mathematical technologies would have major consequences, including: (a) the systematisation of information on births, deaths and life expectancy, among others, which would guide and sustain the planning and implementation of public policies; (b) surveillance of the health of the workforce, which made it possible to deal with the incipient requirements of an industrialising economy and (c) the emergence of a new analytical healthcare economy, which would foster the inclusion of health in macroeconomic calculations, particularly during the 20th century.

Epidemiology became a prime catalyst in this priority, including the use of statistics (as a barometer of health, a source of knowledge for political management and a strategic vector of the economy). As could be seen in the late 18th century, the "body that monitored epidemics gradually became a place where knowledge was centralised, where all medical activity could be recorded and judged" (Foucault 1994, p. 51). Its techniques were not solely limited to issues directly related to treatment and cures; it also developed knowledge about the *healthy human being* (that is, an experience of the non-ill-man and a definition of the *model man*).

During the 20th century, however, this socio-technical architecture underwent major changes resulting from the expansion of capitalism around the world, as well as the shift from a productive matrix centred on industrialisation and the manufacture of goods to one articulated around consumption. In this way, statistical calculation stopped being a fundamental factor in surveillance and instead became a subsidiary element in another kind of logic: risk control. Even though statistical calculation was initially the main tool of intelligibility for nascent risk societies (Beck 2008), it soon became obsolete. The reason is simple: when we have to deal with global risks in which new developments emerge about which we have no records (such as the mutation of an infectious vector or an accident in a research laboratory) or which cannot be mathematically pre-established (such as the stock market crash or an environmental catastrophe), statistical techniques, as Collier (2008) highlights, give way to *new surveillance* in which risk becomes omnipresent on the planetary scale, rendering statistical calculation a tool that in itself is sterile and useless in the face of new global challenges.

This does not mean that statistics have disappeared from our planning mechanisms; rather, they have been absorbed into other much more complex ones.

In this sense, we have witnessed the birth of new logics, such as *preparedness*. This refers to a rationality of anticipatory action towards potential globalised risk (Collier 2008; Lakoff 2008; Samimian-Darash and Stalcup 2017). It conceptualises and formalises any future risk, either national or manmade, related to the security of people, the economy or national and international policy. It is interesting to note how this preparedness is carried out through new techniques and dynamics like 'scenario-building' and 'syndromic surveillance'. Regarding the former, we should stress that since the threat can appear anywhere and at anytime, a constant state of readiness is created by *building future scenarios* which encompass all possible actions if emergency situations arise (Lakoff 2008). 'Syndromic surveillance', in turn, is a device to constantly monitor *pathogenic agents* directly in real time; that is, unlike the earlier statistical surveillance revolving around the individuals in a nation, this new device directly monitors groups of symptoms that coalesce into categories of syndromes that threaten a specific population in real time (Fearnley 2005a, b; Fee 2001). This surveillance logic, which goes beyond previous calculations of risk and establishes the creation of more general mechanisms of activity and intervention, has been enriched by the use of animals and aerial technologies such as orbital satellites. The use of satellites has ushered in tele-epidemiology, a well-established field, while the use of animal life has given rise to what we shall call bioepidemiology.

## Bioepidemiology and tele-epidemiology

Nowadays, epidemiology is so relevant in the social and political organisation of our lives that several authors have defined it as a preeminent element in the "government of life today" (Villadsen and Walhberg 2015, p. 14). In this vein, Reubi (2017) puts forward the notion of epidemiological reason as an analytical gaze for the analysis of the logic that knits together a multiplicity of different technical, political and social elements: the ethical and institutional imperative to save lives, experts such as epidemiologists and doctors, political notions like global health or techniques similar to surveys. Walhberg and Rose (2015), in a more general sense, defend the expression "novel epidemiological style of thought" in its description of a new approach in the field of global health that shifts its focus from events of life (disease and death) to social processes and events of living (disability and health). Populations continue to be seen as biopolitical objects; in fact, Lakoff (2015) has argued that, in this new epidemiology, a sort of real-time biopolitics can be observed. On the other hand, following Whalber and Rose, populations have been transformed, and they have been conceptualised in terms of levels of health and quality of life. This transformation, carried out along a series of new indices, scales (QALYs, DALYs, DALEs, HALEs) and concepts (impairment, disability or severity), has produced a new governmentalisation of living in which the social and personal consequences of living with disease are not only an object of political concern but also the target of public and private strategies of intervention. This line of study is fascinating, and reveals a fundamental shift in epidemiology. However, it can be enriched by analysing the role that smaller technologies and mechanisms

such as drones play in the discipline and, in this sense, add increasing analytical depth to the aforementioned transformation.

As several authors have pointed out in recent years (Gabardi 2017; Hinchliffe et al. 2016; Keck and Lakoff 2013), the use of diverse everyday technologies (sensors, apps, the internet, et cetera) and, in particular, animals has helped enhance and perfect both intervention protocols (preparedness) and future scenarios envisaged by experts. We have termed such use of animals in the exercise of surveillance deployed by epidemiology as 'bioepidemiology'. The usefulness of animals as a tool lies in the fact that their senses have a greater reach than those of humans, and their more acute perception of environmental changes makes it possible to incorporate future environmental alterations into human beings' present reality. In this sense, they may be seen as sentinels, or the heralds of more or less imminent danger. Keck and Lakoff (2013) and Lakoff (2015) repeatedly pointed out that the notion of 'sentinel' has military origins, and refers to an explorer who scours the horizon to detect the presence of the enemy. This figure contrasts sharply with that of the prophet and the forecaster, both of whom face the challenge of mapping out the pathways that will shape the future. However, while the first is a figure who interprets images, sounds, dreams or natural dispositions to announce the arrival of an inevitable (and usually catastrophic) future, the second is a relatively modern-day figure whose information-gathering is essentially based on the calculation of the aforementioned risk in order to foresee and strategically define possible futures. In contrast, the sentinel employs a set of very different practices; the word comes from the Latin 'sentire', to feel or sense, and incorporates an indication of a probable future based on two elements: (a) the knowledge that science is able to build on risk and uncertainty and (b) the variation in the different parameters of some biological element (cell tissue, molecular elements, discharges, bone and muscle material, chemical components, et cetera). In a similar fashion, the life of the sentinel, in the environmental context, becomes the indicator of the appearance of a particular course of future action.

The sentinel provides information about a global variation in the atmosphere or ecosystem that is happening in real time, at a certain speed and generates a future trend. The information provided normally refers to situations of environmental contamination, and such a tendency points to the appearance of instability in the environment. Examples we are all familiar with are the excess of antibiotics in the meat from cows or poultry and the premature death of large bee populations. Keck & Lakoff (2013) and Gabardi (2017) remind us that the use of non-human sentinels to accompany and monitor human activities is nothing new; plants, birds and dogs have been used to gauge safety levels in activities such as mining and fishing since the industrial revolution.

Despite its interest and growing use, bioepidemiology has so far been unable to answer the important questions surrounding the field. There are, for instance, very important epistemological doubts regarding how a sentinel is defined and made fit for purpose, what type of knowledge is at play, who should interpret it and what role non-experts should play in it (animal handlers, farmers, et cetera) (Keck and Lakoff 2013). Ethical issues have also been raised regarding the type of rights that should be granted to the sentinel, and the decisions taken by experts about the level of

involvement in contaminated environments that may be required of non-human living beings used in epidemiological practices (Gabardi 2017). Finally, there is a whole constellation of questions concerning the decision-making involved in the mobilisation of community resources in response to the detection of chemical or biological anomalies by a sentinel (Hinchliffe et al. 2016).

These questions point to the two great risks that bioepidemiology currently faces. The first is failing to generate the right action once signals that indicate transformations in the environment are detected. The second, though it might seem paradoxical in relation to the first, is triggering over-reactions to threats that are not quite concretised. The need to overcome these shortcomings and enhance the activity of bioepidemiology has prompted the recent upsurge of what is known as tele-epidemiology.

A phenomenon that we have witnessed over the last two decades is the convergence of the production of epidemiological knowledge and the use of communication systems, in particular of aerial and orbital media-like satellites. Specifically, the production of images and global positioning (GP) maps would appear to be revolutionising interventions in global health issues. As Peckham and Sinha (2017) point out, the emergence of infectious-disease vectors is a phenomenon that was first defined as a global security problem in the late 1980s. To address it, resources, protocols and technologies were deployed that had previously belonged in strictly commercial or military domains, and were uncommon in the area of health. A good example of this deployment cited by these authors is the use of treatment via satellite in the most recent Ebola outbreak in West Africa.

This convergence has been labelled tele-epidemiology; it combines space technology with animal and human health, and places special emphasis on the connection between infectious outbreaks and climatic and environmental variations that may be tracked using orbital media. This sort of intervention is deemed to have four advantages. Firstly, it eliminates the classic health risks associated with action on the ground: the contagion of health workers, accidents and violent events. Secondly, it provides information of a global and generalised nature which makes it possible to anticipate the future movements of an outbreak, indicating which regions or countries will be affected and calculating probabilities about the sequence of such developments. Thirdly, this level of prediction, combined with image-based knowledge that is thus very easy to use by experts and non-experts alike, is believed to facilitate the level of intervention in the infectious-disease vector. Finally, the knowledge that tele-epidemiology offers and the consequent level of action come very close to the dream of simultaneous detection and intervention (Koch 2015, 2016; Woolhouse et al. 2015).

Nevertheless, tele-epidemiology also presents serious problems that raise questions about both its effectiveness and the regularity of its action. Satellites operate like the eye of God, constantly scanning the planet, amassing information and recording a huge number of images; however, this is relatively contingent because a part of what is recorded is never seen or known. The initial reason for this is that such data must be paid for. This generates a situation in which contracts must first be established between health (for example, the World Health Organisation)

and the military or commercial stakeholders. On many occasions, the strategic interests of the latter may serve to block or significantly distort the management of these data. Secondly, the data must be selected, processed and interpreted. This also requires the development of protocols that determine what to watch, how and where, and, of course, the experts to define such protocols. Finally, both the images and the general knowledge generated by tele-epidemiology need to be checked by studies on the ground. Along these lines, Pigott et al. (2014, 2016) suggest that this very novel way of practising epidemiology has yet to resolve a problem already present in classical epidemiology: the localisation and maximum attention given to a possible infectious outbreak might be diverting experts' attention and intervention from other possible foci of infection.

As may be observed, tele-epidemiology offers a vertical view of an infectious vector that should be complemented by a horizontal one. This might very well be the role of a sentinel; in other words, bioepidemiology. Nevertheless, the question remains as to how to articulate the two views or monitoring exercises. Several very recent experiments exploring this topic, which have attracted our research interest, suggest that the diagonal line which could join the aforementioned vertical and horizontal lines is drawn by the massive use of drones in epidemiology. They can bring the eye of God in the shape of a satellite closer to the sentinels' experience on the ground. The association between drones and epidemiology is a rarely discussed field, yet it threatens to transform a host of our everyday practices and concepts on what security and risk entail.

As explained in the Introduction, in the following sections we should like to analyse all these transformations in a research project, the aim of which is to track the variations experienced in recent decades by the forms of vigilance in epidemiology. This paper presents our conclusions after analysing public and open documents which describe several research initiatives using drone technology in epidemiological emergencies.

## A brief sociocultural analysis of drones

### What is a drone?

Drones are often regarded as devices from and exclusive to the past decade. However, their real origin dates back to the 1990s, when they were known as UAVs (Unmanned Aerial Vehicles), and there is even some military documentation that points to their very early use in the Vietnam War. As stated in "Joint Publication 1–02" from the United States' Department of Defence, a drone can be defined as (Fig. 1):

> A powered aerial vehicle that does not carry a human operator uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable and can carry a lethal or non-lethal payload. Ballistic or semiballistic vehicles, cruise missiles and artillery projectiles are not considered unmanned aerial vehicles.

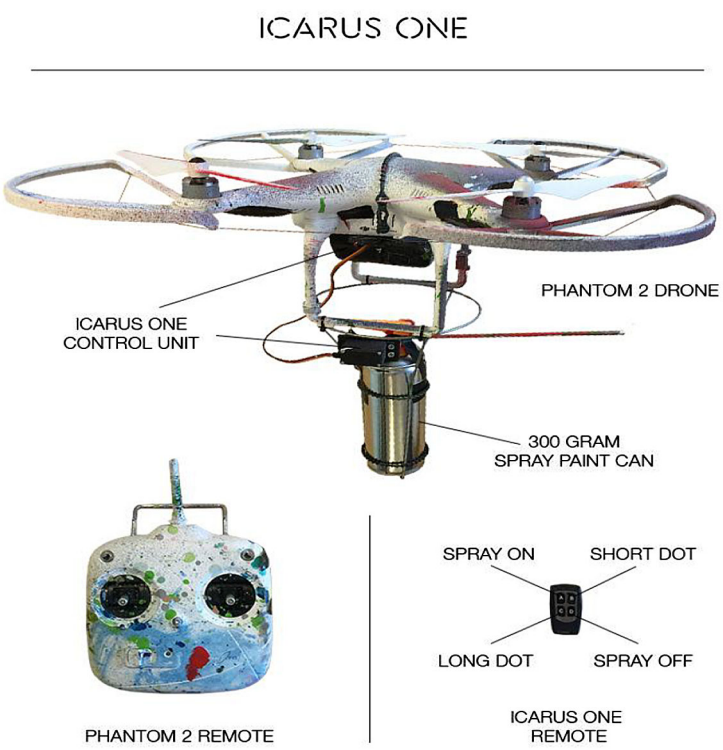


**Fig. 1** The structure of a basic drone

The illustration shows the structure of a basic drone. As stated in the quoted passage, the first major feature and advantage provided by drones when compared to other forms of surveillance is the physical absence of the human factor. This is extremely important in direct work in highly dangerous areas (because of war, environmental disasters or biotic risks like epidemics), while drastically lowering the cost of surveillance. There are different kinds of drones depending on their purpose: (a) targets, which are used in defence; (b) recognisance, which send military information; (c) combat, which carry out dangerous missions; (d) logistics, which carry cargo; (e) research and development and (f) commercial and civilian, which can shoot films.

In addition to their operation, drones are also classified by type. They include: (A) Aeroplane: lift provided by a stationary wing system; they may have propulsion. They cannot hover in place and can only move in one direction. They are more autonomous than other vessels. (B) Helicopter: Lift provided by rotating wings (a single rotor to provide lift); capable of hovering in place and displacement along 3 axes. They are less autonomous but more expensive and complicated to maintain than aeroplanes. (C) Multirotor: Lift based on the principle of rotating wings (several rotors provide lift). More flight stability and simpler mechanics than helicopters (they have fewer breakdowns and lower maintenance costs). Depending

on the number of rotors, there are tricopters, quadcopters, hexacopters, octocopters and so on.

Initially, the use of drones was very restrictive. They were limited to the military and the free-time use of a few aficionados. Nonetheless, over the past decade they have expanded considerably and reached fields such as epidemiology.

## The era of the drone

It is clear that a drone is much more than a robot with wings, cameras, radar or wheels for landing; it is also a technology, which has a social insertion and social uses. Therefore, it entails the deployment of cultural practices around it, the production of meanings and the creation of new interaction rituals, which both presuppose and incorporate it. In this sense, it can be regarded as a social enigma that is still awaiting in-depth cultural analysis; however, this does not mean that the first analyses have not yet appeared, and Luján (2015) is a pioneering author in this field. His main thesis centres around the concept that drones are conglomerates of social relations in the guise of a war, an invisible war that sprang from the logic of the fight against terrorism which feeds the systems of violence that characterise society today. In this sense, drones reinvent our way of viewing war, surveillance and relations with countries defined as 'dangerous'. In a broader view, Chamayou (2013) warns that the revolution entailed by the massive use of drones has barely begun; drones will impact economic niches, our conception of transport and the redefinition of the right to keep watch over and defend oneself. A host of other contributions could also be cited. As Shaw (2016) reminds us, firstly, drones have an essentially ludic sociocultural use that sheds light on changes in our way of viewing entertainment, communication and some community services. Secondly, drones are a technology that affects our conception of security and our notions of local and global.

In this sense, it is likely fair to say that the military domain is where most drone analyses of a sociocultural nature have been made. Authors such as Gusterson (2016) and Rosenblum (2017) have extensively documented the security of countries like the United States, which rests on the extensive use of this technology. War zones such as Afghanistan, Pakistan, Somalia, Yemen and a few other countries have been, or continue to be, witnesses to the systematic and strategically planned activity of drones, the role of which is much greater than simply that of a new weapon to be used against an enemy army. First and foremost, they are directly responsible for killing and injuring thousands of civilians, including women and children, besides destroying homes and property, making them a global menace that reaches well beyond the immediate battle zone, affecting civilian populations and infrastructures. Moreover, they have introduced a logic to justify the defined and permanent monitoring of hostile populations. They have broken the classic international rules of war because they erase the distinction between fighter and civilian, thus establishing an asymmetric logic in which lethal drones are a weapon used by rich nations to attack poor, defenceless ones. These analyses point to a future scenario in which drones are regarded by the wealthiest countries as a necessity and form the foundations of the security and protection of their

infrastructures, leading to the inevitable emergence of a large and lucrative market for such technologies. In these scenarios, our planet is controlled by millions of drones, of differing sizes and functions. Drones hover over every continent and police the world's food supply, control illegal immigration and effectively fight everything from petty crime to civil wars; and, obviously, work to control infectious diseases.

It is clear that like so many other technologies, drones lead toward a sociocultural transformation the likes of which we are just now beginning to glimpse and analyse. Most of the literature published to date, as mentioned above, stresses their relationship with the logic of war and confrontation; however, we believe that this aspect is superficial and conceals a deeper metamorphosis which refers to the conceptualisation of surveillance and its implementation practices. Again, as mentioned above, the use of drones in a science like epidemiology is fertile ground for analysing this change. We shall do so by examining several projects that are underway to make the technology of drones the pivotal point of epidemiological action.

## Drones and epidemiology

The uses of drones far exceed the uses mentioned in the previous sections. In the field of epidemiology, specifically, they are beginning to be widely used in matters related to mapping territories, monitoring, use as rescue equipment, delivery of medications, surveillance of borders, recordings, gathering samples, tracking strains and contagious groups, among others. Some particularly important initiatives include:

(1) The "senseFly eBee" project. Its aim is to map the areas on the island of Borneo affected by a specific strain of malaria (*Plasmodium knowlesi*) which usually affects macaques and is currently spreading among human beings. The purpose of the project is to use drones that enable infectious vectors to be controlled before they interact with humans. To this end, the movement patterns of the monkeys and human beings are mapped through GPS: local people are asked to wear GPS location devices and macaques are equipped with GPS collars almost identical to the human collars. In this way, the researchers seek to identify where and when human beings and macaques are most likely to interact.

(2) Furthermore, drones are also being used to study the health convergence of fauna and livestock. A study published in PLoS ONE examined the spatial epidemiology of tuberculosis (TB) in the ungulate community in Doñana National Park (Spain) by modelling the abundance of three species (deer, fallow deer and cattle) through the use of drone surveillance. The high-resolution images captured by these drones have allowed: (a) the environmental factors that regulate the abundance of hosts to be identified; and (b) the spatial risk of TB in the entire ungulate community to be evaluated. Thus, the ecological, epidemiological and logistical conditions that enable

drones to be used to study the health interface between fauna and livestock are analysed, which is extremely important when researching shared infections in multi-host systems in areas of high epidemiological risk.

(3) Indigenous communities in Peru supplement their traditional knowledge of the environment they inhabit with a DJI Mavic Drone, which they use to monitor oil spills caused by petroleum mining companies. The aim of this initiative is to generate images of remote jungle regions and send them to the relevant companies or authorities in a matter of seconds, something which formerly would have taken days or weeks.

(4) Despite the usefulness and novelty of the initiatives outlined here, the most ambitious and complex initiative to date is probably Microsoft's *Premonition Project*, which seeks to increase the efficacy of detecting infectious outbreaks in a ground-breaking, novel way: by detecting these outbreaks before they reach people. Our research has looked at this project in particular detail.

The *Premonition Project* (a large amount of information about its development is completely free on the internet) entails a huge shift in techniques like syndromic surveillance inasmuch as the goal is not solely to monitor symptoms in real time, but to stop them from appearing at all. As Ethan Jackson (Microsoft 2015), the head of the *Premonition Project*, says, the underlying idea is to use robotic traps (that is, drones) to capture mosquitos and take advantage of their ability to locate and extract the blood of animals as a natural sampling method. The next step is to analyse the genome of the mosquitos to check what infectious diseases they are carrying through "cloud computing", with the goal of sequencing the metagenomic data obtained. In this way, thanks to the latest advances in molecular biology and genetic sequencing, the samples can be processed quickly and cheaply; subsequently, even viruses that have not yet been classified can be detected. Thus, by developing cloud databases, the heads of *Premonition* hope to construct a system that is capable of detecting biological threats before they become real threats.

Various elements of this project deserve special attention. Firstly, mosquitos are used as a very special kind of sentinel; they take blood from animal species living in total freedom, doing so at relatively high speed and over wide areas that are inaccessible to many traditional health workers. Mosquitos live for, on average, 20 days, consume 2.5 μl per blood meal, can fly several miles and are widely distributed geographically. They have advanced olfactory systems to locate hidden prey; they naturally live in rural and urban environments and can sample the genes of animals and their pathogens. It is viewed that their action can leverage classical entomological methods. Secondly, the project employs a whole range of smart traps that automate field biology. Existing mosquito traps are too low-throughput; they need to be placed by experts, remain in the environment for 12–18 h, are heavy and require manual human processing. A third aspect is drone-based autonomous deployment for high-throughput. In this system, drones lay traps in places that cannot be reached by a human being, gather and transport data (mosquitos) over great distances much faster than classical epidemiological systems. Finally, the samples are used to perform metagenome analytics to automatically identify threats, and experts sift through a wealth of biological data to pick out candidate threats. The

combined result of all these elements is a circuit consisting of the following stages: (a) animals maintaining pathogens in their environment; (b) mosquitos collecting blood and sampling pathogens; (c) drones deploying autonomous traps and collecting and transporting mosquitos; the drone covering long distances; (d) laboratories collecting mosquitoes and sequencing genes and detecting pathogens; (e) finally, global pathogen maps of genes in space and time showing the movement of potential pathogens and hosts. The one very simple objective that permeates this whole infrastructure is to see which pathogens are circulating in animals before they impact humans. This knowledge makes it possible, therefore, to devise intervention scenarios that will head off any infectious outbreak before it appears, thus minimising both the human health and the economic threat that it may pose.

As we can see in these examples, even though the idea of 'taking to the skies' to get a broader perspective is not new, the use of drones implies a drastic qualitative change. It entails the advent of a close vertical perspective with extremely sophisticated precision, which is cheap and generates plentiful data which were unknown until now. It is true that for years epidemiologists have worked with satellites and sensors to monitor the movement of animals capable of propagating contagious diseases, but now, thanks to drones, the level of precision and articulation has increased exponentially. The use of epidemiological surveillance centred on drones means going beyond the real-time monitoring achieved through bioepidemiology and tele-epidemiology inasmuch as it seeks to anticipate the existence of a patient zero in human populations. Furthermore, it breaks with the logic of monitoring itself as much as it combines the mechanisms of direct action; that is, a drone does not only see and monitor infectious vectors in real time, predicting (through information) how they interact with human beings; it is simultaneously a tool that can act almost instantaneously, for example by sending medications to dangerous zones, gathering samples and/or tracking contagious groups. Yet that is not all. Additionally, avenues of research are currently being developed that allow drones to achieve incredible degrees of 'autonomy' in this field of action. Along these lines, a team from the Department of the Science of Computation and Artificial Intelligence at the University of Alicante (Spain) has developed a system that has *drones that will be smaller, cheaper and capable of performing jobs totally autonomously*. The novelty lies in the fact that this kind of second-generation drone does not require constant human supervision, as they have enough autonomy to change their course with the ultimate goal of fulfilling their mission.

As posed clearly in the *Premonition Project*, the new epidemiology must combine the development of multi-drone networks with the action of artificial intelligence systems. They have multiple uses due to being programmable devices, and these uses run the gamut from the development of aeroplane pilot assistance applications to the development of independent action systems. The most noteworthy examples include co-operative searches for resources which improve both the time and the safety of systems with just a single drone; delivering packages with the ability to calculate the optimal route in real time and developing a surveillance patrol that is distributed and coordinated in real time.

Another important element to highlight is the new relationship established with animals through the use of drones. Just like in bioepidemiology, the animals operate as sentinels, but now undergo a sort of monitoring and integration in a much wider system than that which they belong to, and to which they contribute relevant data. Moreover, they can now be readjusted and reprogrammed in their biological activity, something which does not happen with the classic sentinel. Modifications in their biological system that occur naturally and spontaneously in the environment are no longer as important as the action taken by a sentinel operating in a much broader artificial device. The connection between animals and drones makes it possible to draw the aforementioned diagonal line connecting the purely vertical and visual activity of tele-epidemiology with the horizontal action of generating information characteristic of bioepidemiology. The drone increases the scope for on-the-fly intervention and continuous adjustment of the system. Furthermore, as the very name of the Microsoft project indicates, this new bio-tele-epidemiology blend is able to stay ahead of the onset of infectious outbreaks in human beings.

Lastly, all of the initiatives mentioned have a common denominator, albeit most clearly in the case of the *Premonition Project*: the significance of movement in the production of knowledge. The biological and chemical knowledge offered by sentinels or the visual knowledge (maps, et cetera.) placed at our disposal by satellites are incorporated in a logic that gives pride of place to the trajectories and vectors of mobilisation. It is precisely on this movement in itself that the possibility of predicting infectious outbreaks rests. The Microsoft project is very clear in this respect; the end product of this surveillance system is a map of pathogenic genes and animal hosts in movement that is created thanks to mass movement: that of mosquitos, drones and data. We find ourselves before a logic of action whose rationale is more than time and space; it is motility itself. This movement (of drones, mosquitos and more) is symmetrical with its main objective, or enemy, namely infectious vectors, and inasmuch as an epidemic does not respect borders and calls for joint international solutions, it blurs the legal-political borders of nation-states.

The new forms of epidemiological surveillance through drones, therefore, are themselves a vector which requires concepts like sovereignty to be renegotiated; however, what changes does the use of drones imply compared to previous surveillance systems? Briefly, we can identify three. First, we are no longer just monitoring infectious vectors in real time (as in the case of bio and tele-epidemiology); instead we are also taking *direct action* in this immediate time. Secondly, there is a general redefinition of the social-technical network comprised of surveillance devices in the sense that the human factor is losing prominence in the equation in some cases (as we can see in the "*Premonition*" and "senseFly eBee" projects). Finally, we are shifting from tracking global flows (like defining a virus' course) to *generating* these flows (through drones' direct action, as well as by redefining legislative-regulatory concepts in domestic and international law). For example, one consequence of the *Premonition Project* is the future use that could be made of drones in conjunction with animals (insects) to influence other animal populations which are carriers of pathogens, and alter their population sizes, their migratory movements or contact with other living beings. We shall now provide

further details on the conceptual revolution being brought about by these three factors.

## Drones: a new anatomy for surveillance

There is never an endpoint for monitoring action in the logic of bio and tele-epidemiology (preparedness and syndromic surveillance is a never-ending story). Its activity is ongoing inasmuch as risk will always be present; instead, protocols are devised and periodically reviewed. We therefore establish clusters of pathogens and symptoms and redefine them according to symptom changes. Likewise, we always start from a middle ground, and there is no specific 'telos' that guides its exercise; that is, we operate with accumulations of data from the past in order to understand the present and make future projections that could shape coherent actions. These surveillance systems are always exercised in the short term; they are specific, continuous and unlimited. The most interesting thing about their surveillance is that it strives to anticipate any kind of risk. Trajectories are predetermined and then monitored. For example, imagining a monitoring device capable of showing the position of a contagious element in a simulated environment is no longer science fiction. Once the risk or threat appears, intervention takes place after an analysis which strives to be as prompt as possible. Regardless, these systems share a common denominator with the classic surveillance logic that was based on forging a relationship with punishment: there is a separation or exterior relationship between the object being watched and the device monitoring it. There are efforts to reduce this space to the minimum by accelerating future projection, analysis and intervention processes; however, it remains there, like an unbridgeable abyss. Indeed, this separation is the ultimate cause of the problems that plagued both bio and tele-epidemiology: between significant or alarming data being recorded and action being taken, there is always a gap, however small it may be.

Nevertheless, drones are bringing a new anatomy to surveillance which relies on movement, does not require previous visibility and transcends physical and biological barriers. It is actually based on the management of movement. Surveillance in a drone system transcends time, which is particularly evident in its capacity to store and retrieve information from databases that allow the course of the drones to be altered and their autonomy modified. As noted in the *Premonition Project*, drones do more than just trace movement; they intervene almost immediately, and with their own movement they transform the flows and courses of infectious vectors. In short, they transform the emergency situation. The drone instates a kind of surveillance which we could call pre-signal or pre-symptomatic. It tries to anticipate the appearance of the illness itself, and if it does not, then it tries to get ahead of its transmission. To do so, the drone's course mixes, connects or joins with that of the dangerous object. Ultimately this kind of capture entails crossing the abyss between the risky object and the surveillance device. Even though the logic of both bio and tele-epidemiology aspire to fully determine the movements of the threat, a kind of incorporation or capture occurs with drones. The course of the threat is incorporated into the course or flow of the drone. This is very

clear in the *Premonition Project*: the maps produced from the activity of the whole surveillance system are totally dependent on the trajectories and aforementioned stages of the drones, the place where they have laid the mosquito traps, the space where they have taken the samples, where and when they have transported them, et cetera. So what exactly is surveillance like in this model? It is simply generating assembly surfaces or merging surfaces. What do they assemble? Two courses: that of the health emergency and that of the drone's.

In this merging, the course of the emergency is diverted, removed from its usual territory and context of movement and deployment; it is translated into the discreet flows determined by the drone system. The main consequence of this intervention, this reassembly of courses, is that the threat becomes a new entity which can then be analysed from another perspective, and in particular become the object of intervention by developing statistics, comparisons and more. An important element to note is that the thread is established before it can be a problem for humans. A reassembly produced in this way is connected with other entities, in other contexts, and ultimately becomes a part of other logics. The outcome is the emergence of a new course which disembodies the threat, turns it into data (images) and into a technology interface which is composed of those contact surfaces between the order of the threat and the drone. The assembly surface thus generated relies on technology that makes and records discreet observations and establishes a risk-order continuum. Inside it, movement ceases to be a simple unit that can be monitored and instead becomes a flow determined by the drone.

The assembly surfaces outstrip both the notion of risk and the notion of the very space and time of the threat; in fact, they situate it in an event that is defined by the drone's actions. The goal is no longer to monitor the surreptitious outbreak of an infectious vector and intervene as quickly as possible, nor is it to gather information on the affected cases and group them into categories or clusters or to try to formalise or represent the risk; now, with the intervention of drones, the goal is to know with which of the drone's actions the element of contagion works, with which maps of pathogens movement, with which of the drone's action-movements it connects with the element of contagion and how they assemble. Surveillance takes on a new guise of being-assembled-together or being-assembled-with on the plane or image of movement.

## Conclusions

For decades, the main authoritarian temptation in terms of surveillance has been characterised by the literary metaphor in the George Orwell book 1984. There have been endless fears of the development of a central, sole watch-point that could track all our everyday activities and penetrate into the most private spaces of our thinking and behaviour. Some authors claim that cyberspace's encroachment into our everyday life has brought this threat to fruition and that it is close to becoming a reality. Constantly recording the information that we are required to leave behind in the networks of our daily lives (economic transactions, private communication, learning exercises, free time, etcetera) and its subsequent handling by certain

government information agencies has led us to enter this dark world of perpetual surveillance that tracks our every move; however, despite the seamlessness of the relationship between our offline and online realities, there are always spaces of resistance that are defined in the former. If we are being watched through the cameras on our computers, we can turn them off. If our credit card purchases are being recorded, we can always pay in cash. If our literary or film tastes are analysed through our searches in online stores, we can always choose a physical book, which we purchase at the corner shop.

Doubtless, the use of drones in epidemiology is changing the effectiveness of the discipline. As detailed previously, the relevant problems connected to intervention can be solved. Drones seem to be the mechanical arm that epidemiology has been looking for throughout its history, thus enabling it to act quickly and quasi-immediately. Nevertheless, as we have tried to argue, their use points to something more important than a technical solution. The encounter between epidemiology and drones is going beyond a mere 'new style of thought' or 'a novel reason'; it seems to announce the arrival of what Foucault (1995) called a "new ontology of the present". A new ontology in that the anatomy of surveillance experiences an interesting transformation because drones fully alter the logic we have just described in the previous paragraph in two ways. First, they eliminate the physical space of resistance to the formalisation and surveillance entailed by cyberspace; secondly, the connection between drones and artificial intelligence devices seems to foretell a total control which makes it feasible to register virtual movement as real. However, the new development in our conceptualisation of surveillance goes beyond the actualisation of the great Orwellian fantasy (Orwell 2018/1949). Drone surveillance is not limited to recording information or processing visual data. The device acts directly on the target being watched. It acts in the course of its development and seeks to change it; therefore, drones are a mechanism of intervention which capture courses and re-categorise them in order to transform them into more manageable and codifiable courses according to their own operating principles. As stated at the beginning of this text, drones monitor by creating their own flows of movement and development. To some authors, this may point to the advent of an Orwellian and claustrophobic dystopia that heralds action which is almost pre-symptomatic. To others, this may mean a total revolution in the field of prevention. It would allow the lives of animals and humans to be saved before an epidemic actually breaks out; it would mean control over the infectious vectors which have accompanied human beings throughout our history. As the philosopher Martin Heidegger said, citing a verse by Holderlin, the best way to conceptualise our technological advances is by understanding that they could pose a danger, but that "wherever a threat is born, salvation also appears".

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**Francisco Tirado** is a Senior Lecturer at Universitat Autònoma de Barcelona. Throughout his academic career he has been working on topics such as: cyborgs, new ways to rethink social order, actor-network theory, biopolitics, socio-technical relations, the relation between the idea of event and objects… He has worked with concepts like extitutions or kinepolitics and currently is working on topics related with biomedicine and biosecurity.

**Pedro Torrejón Cano** has a degree in Psychology from the Universidad Oberta de Cataluña and a Master in Psychosocial Intervention and in Human Resources from the Universidad Autónoma de Barcelona. He is currently is preparing his thesis about biosecurity and protocols in the European Union.