Routledge Research in Applied Ethics

THE ETHICS OF DRONE DESIGN

HOW VALUE- SENSITIVE DESIGN CAN CREATE BETTER TECHNOLOGIES

Dylan Cawthorne

ROUTLEDGE

The Ethics of Drone Design

This book presents a holistic approach to the design and use of drones. It argues that this powerful technology requires high levels of ethical analysis and responsibility – our moral progress must keep pace with our technological progress.

Drone technologies support and diminish the flourishing of certain human values, impact power relations between individuals and groups, and add an additional element to the complex network of humans and objects in modern society. The book begins by introducing four prototype drones designed and built by the author: the healthcare drone, the search and rescue drone, the educational drone, and the spiritual drone. These drones have been developed using a value-sensitive design approach – with values such as human welfare, privacy, trust, environmental sustainability, and justice at the forefront. Ethical analyses and social impacts are taken as design inputs, leading to the creation of better, more responsible drone designs. The book then showcases additional methods used to develop the prototype drones from the fields of engineering, ethics, and art, including ethical frameworks, ethics standards, capability caution, and speculative design. The holistic approach reveals a more subtle and nuanced view of drones than the currently polarized characterization of "the good drone" or "the killer drone". The book concludes with recommendations for drone engineers, companies, lawmakers, and citizens on how to support ethics in drone design.

The Ethics of Drone Design is an essential resource for scholars, advanced students, engineers, and designers interested in the ethics of technology.

Dylan Cawthorne is Associate Professor at the Drone Center at the University of Southern Denmark. His main area of research is using value-sensitive design methods and ethical principles to develop and build prototype drones for humanitarian, public healthcare, search and rescue, and educational purposes.

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How Value-Sensitive Design Can Create Better Technologies

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1 Introduction

This book presents a holistic approach to the design and use of drones. It argues that this powerful technology requires high levels of ethical analysis and responsibility – our moral progress must keep pace with our technological progress. Drone technologies support and diminish the flourishing of certain human values, impact power relations between individuals and groups, and add an additional element to the complex network of humans and objects in modern society. First, drones and ethics are briefly introduced. Then, four prototype drones designed and built by the author are introduced: the healthcare drone, the search and rescue drone, the African mapping drone, and the spiritual drone. Each of the drone design chapters begins with the relevant ethical considerations, followed by the social context, culminating in a technological embodiment – a drone design. Each chapter ends with a meta-ethical consideration – should this drone be built at all? The methods used to develop the prototype drones are showcased in the next chapter; these come from diverse fields, including engineering, ethics, and art: value-sensitive design, ethical frameworks, capability caution, and speculative design to name a few. These methods reveal a more subtle and nuanced view of drones than the currently polarized characterization of “the good drone” or “the killer drone”. The book concludes with specific recommendations for drone engineers, companies, lawmakers, and citizens aimed to support the flourishing of humans and of nature in the years to come.

This book is written first and foremost for engineers, and the engineer’s role and perspective are taken as the default positions. There are few books about ethics written for engineers by an engineer, and that take into consideration how engineers work and think. Philosophy and ethics can be formidable subjects for anyone, and engineers – usually focused on the material aspects of life – may find the abstract nature of these topics particularly daunting. This book addresses the disparity in a multitude of ways, including its sequencing (examples first, then methods), style (lots

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of images and tables), formatting (numbered chapters, sections, and subsections), and language (mostly third person, minimal use of rhetorical questions).

1.1 Drones

Drone is the common name for an uncrewed aerial vehicle (UAV)[1]; some examples of common drones are shown in Figure 1.1. Drones are flying robots that exhibit some level of autonomy, and which may be remotely piloted or pre-programmed to execute set routes. Simple drones are similar to remote control aircraft as both are remotely operated systems, but remote-control aircraft lack autonomy. Drone autonomy can include simple tasks such as stabilization – for example, quadcopters have onboard sensors, which allow the drone to fly in a stable manner (they are inherently unstable and would be virtually impossible to fly manually). Or, the automation can be more complex, such as sensing the world and making decisions based on these inputs – for example, having sense-and-avoid capabilities.

In this book, a drone is:

- An aerial vehicle that exhibits some level of autonomy, and which may be remotely piloted or pre-programmed to fly set routes

Common drone configurations include fixed-wing, VTOL (vertical takeoff and landing), and multirotor – such as the four-rotor *quad*copter, six-rotor *hexa*copter, and eight-rotor *octo*copter) – see Figure 1.1. The multirotor is the most familiar configuration; it uses multiple upward-facing propellers to generate lift and to allow for maneuvering. Fixed-wing drones fly like conventional aircraft. Fixed-wing drones are the most common in

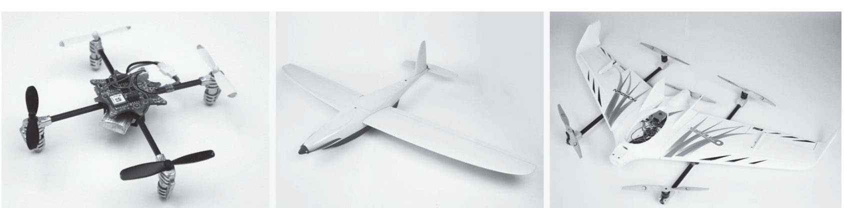

Figure 1.1 Three common drone configurations – a small multirotor helicopter (left), a fixed-wing drone (center), and a vertical takeoff, and landing (VTOL) drone (right).

Source: Images by the author.

industrial applications outnumbering rotary wing drones by around two to one (“Remotely Piloted Aircraft Systems Yearbook”, 2016). VTOL drones combine the capabilities of vertical takeoff from the multirotor and adds the efficiency of flying on fixed-wings but adds complexity and drag. More exotic drone configurations, such as flapping wing and lighter-than-air (blimps), have also been developed. The focus in this book is on smaller drones weighing under 25 kg and includes examples of both fixed-wing and multirotor designs.

The drone is the mobile part of a larger drone system, or uncrewed aerial system (UAS). The drone system includes the drone along with the remote control or ground station and any additional support systems such as a launcher, landing/recover system, and command-and-control infrastructure.

Drones vary considerably in size, weight, configuration, and capability. The size and configuration of a drone are important high-level design considerations and influence key performance characteristics such as the usable payload, range, and flight speed – as well as social and ethical attributes. The drone shown on the left in Figure 1.1 is an example of a very small but highly capable quadcopter. It weighs 50 grams but has a GPS receiver and can navigate pre-planned routes. On the other side of the size scale is the Northrup Grumman Global Hawk, a fixed-wing military reconnaissance drone. It weighs almost 15,000 kg and has a wingspan of 40 meters (“Global Hawk,” 2023). The now ubiquitous camera-equipped hobby drones – such as the DJI Phantom and Mavic – are usually relatively small quadcopters weighing between 250 grams and a few kilograms (2023a). In principle, any aircraft could be made into a drone by replacing the onboard pilot with a remote pilot. The Firebird developed by Scaled Composites is an optionally piloted aircraft that can be operated by an onboard pilot, or remotely as a drone (“Northrop Grumman Firebird,” 2022).

1.1.1 Good Drones and Evil Drones

The recent development of drone technology has been divided into two eras: the era of the Predator starting in 2003 and the era of the Phantom starting in 2013 – the year when non-violent drone use outpaced that of military drones (Choi-Fitzpatrick et al., 2016). The era of the Predator – the infamous armed U.S. military drone (“General Atomics MQ-1 Predator,” 2022) – represented for some the era of the “evil” drone, or at least that of the violent drone. In contrast, the era of the Phantom – the small white quadcopter for hobbyist filmmakers (“Phantom (unmanned aerial vehicle series),” 2022) – seemed to offer some relief as an example of a “good” drone. In 2016 and 2020, two books with the same main title, *The Good*

Drone, were published – the former more of a critique of the “good drone” narrative (Sandvik & Jumbert, 2016), but the latter providing examples of drones, kites, balloons, and satellites being used for “the greater good” (Choi-Fitzpatrick, 2020).

Unfortunately, both narratives about drones oversimplify a complex and ever-changing technology in an ever-changing context. The “evil” military drone may not be so evil if it is used to protect your homeland from invasion, and the “good” hobby drone may not be so good if it is used to spy on your family in your backyard. A main objective of this book is to provide a more nuanced view of drones compared with this binary, good versus evil debate.

1.2 Ethics

Ethics is the branch of philosophy that addresses morality and the good life. It includes conceptions of what is considered right and wrong, vice and virtue, as well as ideas about human values, virtues, and human flourishing (“Ethics,” 2022).

The focus of this book is on applied ethics – the practical implementation of ethical concepts into daily life (“Applied ethics,” 2022). Although they may at first appear very different, an objective of this book is to demonstrate the intimate relationship between ethics and drone design. First, this relationship is demonstrated through a series of specific drone design case studies. Later, in The Theory, Methodology, and Practice chapter, applied ethics methods are outlined in general so that they can be used to design more ethically informed drones.

1.2.1 Introduction to Value-Sensitive Design

This book argues that value-sensitive design is a way to create better technologies – specifically, that it can be used to develop drones that support human flourishing *by design*. Value-sensitive design (VSD) is an applied ethics approach to the development of technology which puts human values at the center – it is *sensitive* to human values. Human values are those things which “a person or group of people consider important in life” (Friedman, Kahn, Borning, & Huldtgren, 2013) and include physical, mental, and material welfare, trust, human autonomy, and privacy. VSD is an example of an applied ethics methodology, as well as a way of “front-loading ethics” in that the moral implications of a design are considered from the start of the development process.

VSD consists of three phases, referred to in this book as: *the ethical phase*, *the social phase*, and *the technological phase* as shown in Figure 1.2. These three phases are represented in the organization of the chapters

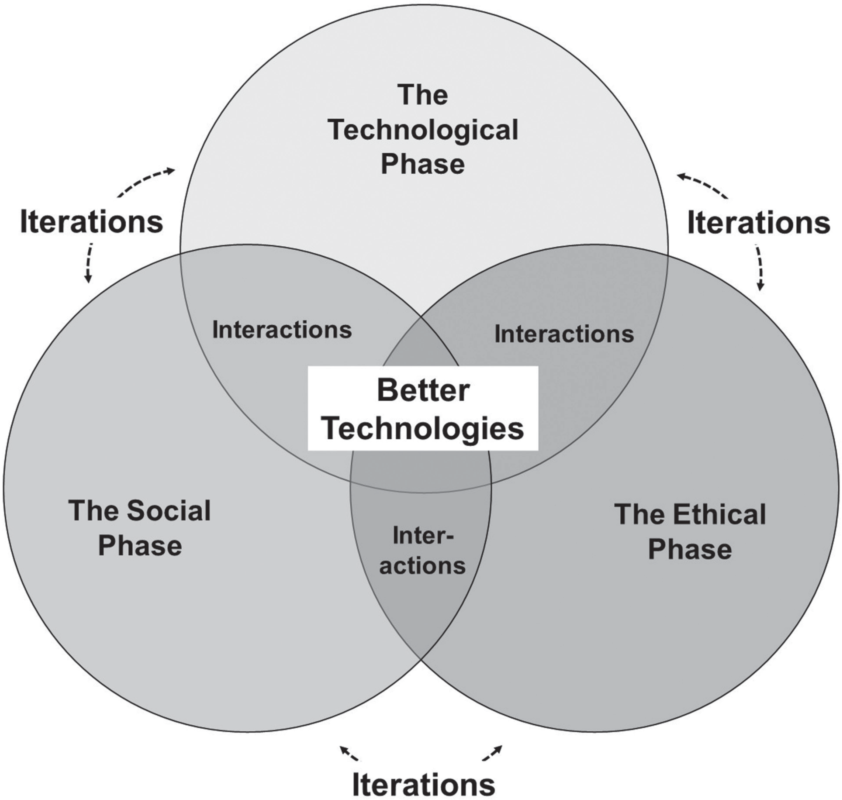

Figure 1.2 Value-sensitive design is an approach to the development of technology, which puts human values at the forefront. It consists of three main phases: the ethical phase, the social phase, and the technological phase. When all these phases – and their interactions – are considered, better technologies can be created.

Source: Graphic by the author, based on Friedman and Hendry (2002).

about prototype drones, that is, the healthcare drone has sections titled *the ethical phase, the social phase, and the technological phase.*

Value-sensitive design was developed by researchers at the University of Washington in Seattle, Washington, in the early 2000s (Friedman & Hendry, 2002). Since then, a multitude of academic papers have been written on the topic, but not many actual technologies have been built explicitly using the methodology. In a survey covering 20 years of value-sensitive design, 219 academic publications about VSD were identified, but only 17 of these actually built technology (Winkler & Spiekermann, 2021). These technologies include a television-based "window" that show a view to the outdoors in a closed office (Friedman et al., 2013), a parent-teen smartphone safety app (Czeskis et al., 2010), and a missile targeting system (Cummings, 2006). VSD's uptake in industry is hard to track since most companies do not disclose their design methods. In this book, the lack of applied VSD to real technologies is addressed through the design of multiple prototype drones.

Design is both the *process* of developing a new product or service, as well as the *result* of that process, that is, the product itself. In this book, the term design is used to designate the engineering process and the technological qualities of an item rather than just its aesthetics (i.e. an attractive "designer" object).

It could be argued that the purpose of all design is to make a (hopefully positive) impact on society, but sometimes this aim is lost in the pursuit of "technology for technology's sake". In addition, engineers can become so specialized and removed from the impacts of their products that they forget about the ultimate aim of their work – to enhance human capabilities. VSD aims to remedy this disconnection and places humans again at the forefront of technological development. This book demonstrates this process through the VSD of several prototype drones, which are described in the subsequent chapters.

Note

1 Drones are commonly referred to as "unmanned aerial vehicles"; however, here the non-gendered term "uncrewed" is used instead. For further reading see (Joyce, Anderson, & Bartolo, 2021).

2 The Healthcare Drone

2.1 The Ethical Phase

In the ethical phase of VSD, human values relevant to the drone design are front-loaded; these are expanded in the following sections, along with the links between the ethical, the social, and the technological phases of VSD.

2.1.1 Human Welfare

Human welfare is perhaps one of the most compelling reasons to develop technology – to improve the conditions we live in; it includes physical welfare, psychological welfare, and material welfare (Friedman et al., 2013). Physical welfare has to do with one's bodily health and well-being. Psychological welfare deals with one's mental state, including mental health and mental well-being. Material welfare is about one's property, finances, and employment.

The Danish healthcare drone is designed to enhance physical welfare by rapidly transporting urgent medical samples from the island of Ærø to Svendborg hospital for analysis. This could reduce the time a patient must be placed in quarantine while awaiting the test results and allow for more rapid treatment if an ailment is discovered. The increased speed of care could also enhance psychological welfare, with people – especially those with medical conditions – feeling more comfortable living farther away from a hospital. The drone could also increase material welfare by reducing healthcare costs, potentially saving the Danish taxpayers' money. It could lead to jobs for drone researchers, pilots, and manufacturers, again increasing material welfare. However, the drone could also be responsible for reducing human welfare, and some of these risks are covered in the following sections (Figure 2.1).

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Figure 2.1 The prototype Danish healthcare drone developed to deliver urgent blood samples from outlying areas to major hospitals for analysis (top). The color scheme is modeled after a Danish ambulance; the drone is neon yellow with a dark green checker pattern on the leading edges of the wings, and the text is in red. The prototype Danish healthcare drone in context during testing at the Hans Christian Andersen Airport (bottom).

Sources: Top image by the author and bottom image by Steffen Nielsen, used with permission.

2.1.2 Safety

The value of safety – that a system should not violate one's physical welfare, injure, or kill – is perhaps the most well-established human value in engineering. Safety is probably the human value that receives the most attention in drone design as well. A common approach to drone safety is the equivalent level of safety. This states that drones should be at least as safe as commercial aviation: less than one fatality per million flight hours ("Specific Operations Risk Assessment (SORA)," 2017). Although many studies suggest privacy concerns may be the risk the public is most concerned about, safety – especially preventing death – receives far more attention from the engineering community.

Drones could cause injury or death by hitting someone on the ground, crashing through a building hitting someone inside, or by impacting an aircraft. The severity of injury when a drone impacts a person on the ground depends on the kinetic energy of the drone – which come from its speed at impact and its weight – as well as the sharpness (or bluntness) of the part of the drone impacting the person (Magister, 2010). Injuries can be caused by very low-impact energies, especially when caused by a sharp object; for example, eye rupture can occur at 4 Joules. Studies vary, but most put the range of impact energy for serious injury between 25 (la Cour-Harbo, 2017) and 200 (Radi, 2013a) Joules. Above 1,400 Joules, a drone can crash through windows causing infrastructure damage and hurting people inside (Clothier, Walker, Fulton, & Campbell, 2007). The risk of downing an aircraft is a serious concern as well. Large, hard drone parts like motors and batteries can rip apart jet engines if ingested – but this risk is minimized if the parts are under 300 grams each (Radi, 2013b).

The prototype Danish healthcare drone is relatively safe. It is a fixed-wing drone; these are more efficient at lifting a given payload and have better range than vertical takeoff (VTOL) or multirotor configurations. Therefore, the drone can be made smaller and more lightweight since the launching and landing equipment does not need to be carried onboard. The drone is small (1-meter wingspan), lightweight (1.4 kg), and relatively low-speed (45 km/h) giving it a fairly low kinetic energy–107 Joules at cruise speed. The wide (15 cm), blunt foam nose with the motor and propeller in the back reduces the chances of lacerations. All of the hard metal components are under 300 grams, including the batteries which are divided into two smaller packs of around 150 grams each.

Since the drone does not take off and land vertically, launching and landing infrastructure are needed at the clinics and hospitals where the drone will be used (see "Support Systems"). The small size is only possible due to the small payload – up to two samples at a time. The drone's required range of 27 km and the need to tolerate some wind also plays a role in its minimum achievable size. Still, the drone's overall inherent safety assessment could be characterized as fairly harmless (la Cour-Harbo, 2017). Additional, non-mechanical safety measures could be used as well, including "geo fencing", which prevents the drone from flying into restricted areas such as airports (DJI, 2023b).

2.1.3 Security

Security, in the context of technological development, is the prevention of harm caused by others ("Security," 2023). A secure system is one which protects its integrity to perform as designed, and which is resilient against harm when they do occur. Security can be conceived of as a spectrum from very secure to very insecure. Often, systems cannot be made completely impenetrable to attack – or it would be unnecessarily complex or costly to do so – but still offer some form of deference against would-be misuse (see "Misuse"). Tools have been developed to identify and counter would-be security threats; one is the security and privacy threat discovery cards, which include consideration of an adversary's methods, motivations, resources, and the human impact (Denning, Friedman, & Kohno, 2013).

The prototype Danish healthcare drone incorporates a number of security-enhancing features. The camera system allows the drone pilot to see the cargo bay during the entire flight (see Figure 2.2), and the clear hatch makes it easy to see what the drone is carrying. The RFID tag system makes it more difficult to carry unauthorized cargo; doing so would require access to the RFID tags at the hospital. The cargo bay's three openings are the size and shape of the intended cargo – the one that is 7 × 7 × 3 cm is the size of a temperature recording device (required to ensure the samples do not get too hot or cold), and two that are 12 × 3 × 3 cm, the size and shape of blood sample tubes. The lock on the cargo bay (although not very robust on the prototype) would reduce the chances of the blood samples being removed by unauthorized personnel – for example, someone that found the drone after a crash. The drone's wide body makes it very difficult to hand-launch, meaning it is much less likely the drone can be successfully deployed without the launch rail and therefore outside of the hospital context. A launching system with a high level of security could be developed, in which the weight of the drone is checked prior to launch (and the system will only allow launch if a payload of maximum 85 grams is detected), as well as an external scan to ensure nothing has been mounted on or strapped to the outside of the drone.

2.1.4 Privacy

Privacy is the ability to decide what information about oneself may be made available, captured, or shared (Friedman et al., 2013). Drones could fundamentally alter the way in which societies and individuals experience (or don't experience) privacy. Many have described private data as "the new oil" (Dance, 2018), referring to its astonishingly high value to marketers (Wu, 2017). And in this digital age, it has become much easier to capture private data. In the past, spying required in-person, covert surveillance using cameras with telephoto lenses, planting bugs in phones, and accessing physical documents (Spiekermann, 2015). Now, under a paradigm of "data-veillance" (Spiekermann, 2015), our most private data is at risk via invisible, remote, networked, and ubiquitous surveillance–to be scooped up and scoured by governments ("Edward Snowden: Leaks that exposed US spy programme," 2014) and companies (Collier, 2020). Drones could add a physical element to the equation, monitoring people in real-time – even those that keep their digital data secure and opt-out of social media and other data-harvesting applications.

Some scholars have warned that drones could lead to a chilling effect in public spaces as well as private areas – where people feel unable to express themselves or relax because they fear they might be monitored at any time (Cavoukian, 2012; Cawthorne & Robbins-Van Wynsberghe, 2020; Thomasen, 2018). The chilling effect has been utilized in the design of the Presidio Modelo, or "model prison", in Cuba (Pohl & Nájera, 2009). The building is circular, with prison cells at the outer edge and the guard tower situated at the center. Small one-way windows in the tower allow the guards to view any cell at any time, but prevent the prisoners from seeing if they are being watched. The mere idea that they *could be* looking is the chilling effect in action.

Needless to say, most people do not want to live in an open-air prison, and a number of privacy-by-design (PbD) approaches have been developed including those specifically for drone design (Cavoukian, 2012; Cawthorne & Devos, 2020; Vivet & Smith, 2016). Privacy is addressed in the section on Capability Caution (Cawthorne & Devos, 2020), and the seven drone PbD principles are (Cavoukian, 2012):

1 Proactive consideration of privacy from the start
2 Privacy as the default setting
3 Privacy embedded into the design
4 Full functionality while maintaining privacy
5 Privacy is ensured throughout the lifecycle of the data

6 The technology operates in a transparent/explicable way (see "Explicability")
7 User-centric design

The drone is not the only part of the system, and therefore it is important to remember that "privacy be built directly into the design and operation, not only of technology, but also of operational systems, work processes, management structures, physical spaces, and networked infrastructure" (Cavoukian, 2012). Using the Danish healthcare drone as an example, if the working practice at the hospital is to label blood samples with the patient's civil registration number (i.e. social security number), their privacy would be at risk when mounted into the clear cargo bay of the drone. Therefore, the working practice should also be modified to work in concert with the drone technology.

Each sensor which can be mounted on a drone has unique capabilities that impact privacy in different ways. The most common – and perhaps the most problematic – is the camera. Drones flying at night carrying *thermal* cameras have been used in Denmark to identify leaking underground district heating pipes ("Drones find leaks in district heating pipes (translated from Danish)," 2018). Thermal cameras cannot capture a person's face but can identify things such as where a person has recently been – a warm car or a hot doorknob. Lidar – a sensor which sends out pulses of harmless laser light in many directions to measure the distance to nearby objects – outputs a point cloud ("Lidar," 2023) rendering individuals somewhat anonymous. Magnetometers – those which detect electromagnetic fields – have been used to detect overhead powerlines without the use of cameras (Malle, Nyboe, & Ebeid, 2021). Sometimes, simple sensors will provide the information needed and have minimal privacy concerns – for example, ultrasonic sensors can detect distances to objects and are useful in landing a drone softly. Infrared lights and sensors on the drone can be used to land accurately without the use of cameras. But perhaps the easiest way to reduce privacy risks and concerns from the public is to not have a camera onboard the drone at all, and to mark it as such (i.e. "no camera onboard" labels).

Companies and researchers have developed a number of technologies which support drone privacy. Some use AI to detect and blur faces and license plates and companies offer blurring services for drone photos and videos in order to be General Data Protection Regulation (GDPR) compliant (Celantur, 2022). This approach uses a high amount of processing power, so only lends itself to larger drones – and one false-negative (i.e. not detecting a face) could lead to a privacy violation. Privacy-aware restricted areas could be established, where property owners could choose (important to note if the default is to opt-in or opt-out) to not have their land overflown by drones (Blank, Kirrane, & Spiekermann, 2018). A prototype algorithm that blocks out private property in real-time onboard the drone has been developed (Devos, 2020). Sometimes, the presence of people is deemed necessary to a drone's operations; in these cases, anonymous video analytic (AVA) software has been used for face recognition to extract the needed data, which is saved in an a log file while the raw image data is discarded (Vivet & Smith, 2016).

In a study about the perception of drones in Denmark (Cawthorne & Frederiksen, 2020), participants found the inclusion of a camera on the drone to be a negative attribute – they did not want their privacy to be violated. This is in line with a multitude of studies which show the public's privacy concerns with respect to drones (Cavoukian, 2012; Luppicini & So, 2016; Scharf, 2019; Thomasen, 2018; Wang, Xia, Yao, & Huang, 2016), as well as other studies conducted in Denmark (Bajde, Bruun, Sommer, & Waltorp, 2017; Bajde, Woerman, et al., 2017). Danes place a high value on privacy, and there is even a social norm that people should have the right to be left alone – including in public.

Value-sensitive design, PbD, and capability caution (see "Capability Caution" and (Cawthorne & Devos, 2020)) approaches were used to develop the camera system on the Danish healthcare drone[1] (Tinggaard & Larsen, 2021). The camera system broadcasts a live-stream video so that the human pilot can actively navigate the drone – which may support meaningful work (see "Jobs") – but which could lead to privacy violations (an example of a value conflict – see "Value Conflicts"). Therefore, the small raspberry Pi computer is used to sense if the drone is operating (via the accelerometers), and varies the resolution of the image it transmits depending on the altitude of the drone (via the barometric pressure sensor) – see Figure 2.2. This means that when the drone is powered on but not flying, no data is broadcast – for example, when the samples are being loaded into the cargo bay, where people would be easily visible. Upon flying, the drone transmits low-resolution video at 144 pixels using an interpolation blurring effect. This resolution is low enough that personal data such as people's faces, vehicle license plate numbers, etc., cannot be collected but is high enough that a human pilot can still easily use it to navigate. As the drone gains altitude, the resolution of the camera is increased until it reaches 1,080 pixels (high definition) at 80 meters altitude. At this height, personal details are too small to be discernable. In Denmark, the European Union GDPR ("General Data Protection Regulation," 2016) are in force, making PbD and data minimization easy ways to ensure compliance with the law. In the future, the data could be encrypted (see the approach used in the chapter "The Search and Rescue Drone") to provide additional privacy protections.

Figure 2.2 Still image from the drone's tail-mounted livestreaming camera; the resolution of the camera varies between 144 pixels at ground level, to 1,080 pixels at altitudes over 80 meters. The image shown is 600-pixel resolution – high enough for the remote human pilot to navigate, but low enough to eliminate many potential privacy violations. Note that the image is transmitted in color.

Source: Image by the author (Cawthorne, 2020).

2.1.5 Calmness

Calmness is a human value often identified in the value-sensitive design literature; calmness is "a peaceful and composed psychological state" (Friedman et al., 2013). Calmness can be supported by eliminating distractions, noise, and stress. Unfortunately, our time and focus is a highly valuable commodity with companies competing to get access to our attention for advertising purposes (Wu, 2017). An extreme example is the advertising campaign used by Uber in Mexico City, where drones – holding signs shaming people for not ride sharing – were flown over people stuck in traffic (Reilly, 2016).

Drones could contribute to a more or a less calm environment. In some cases, a drone could be used instead of a more disturbing technology – for example, a small drone could be used in lieu of a powerline inspection or medical helicopter. However, drones could also contribute to disrupting calm environments. Their visual presence can be a distraction, and their sound an annoyance. It has been found that people are more distracted by moving objects – such as drones – than stationary objects. Drones are being tested in the Bonython neighborhood in Australia by Google Wing. The residents have banded together to try and stop the drones, their high-pitched noise being a major complaint ("Bonython Against Drones," 2023).

It might seem logical to make drones as close to silent and invisible as possible to increase calmness, but this approach has flaws. In many cases, people should have the right to know when a drone is nearby them. This relates to several other human values, including trust, privacy, safety, and explicability. And a nearly silent and invisible drone would make the perfect spying tool – appropriate for a military context, but not in a civil context – implicating dual-use and misuse.

Citizens on the island of Ærø are particularly sensitive to disturbances – the island has the reputation as a calm place to relax and de-stress – making design for calmness particularly relevant. The prototype healthcare drone has been designed to be visible and audible – supporting the value of explicability (see "Explicability"), but to make a less annoying sound and therefore cultivate calmness (Cawthorne & Juhl, 2022). Empirical studies (Cawthorne & Juhl, 2022) have shown that people find higher-pitched drone sounds more annoying than lower-pitched ones. The healthcare drone's 4.4:1 gearbox and relatively slow-turning propeller produce a lower-pitched sound profile than smaller, faster-turning propellers used when no gearbox is present. In subsequent work, one-bladed propellers were developed and tested on a small quadcopter, which reduce the high-pitched "buzzing" sound most drones produce; the single-bladed propellers produce a lower-frequency sound which people find less annoying (Cawthorne & Juhl, 2022).

2.1.6 Jobs

In value-sensitive design, employment is considered an important human value and is associated with material welfare (see "Human Welfare"). People derive a lot of their identity from their work, and meaningful work can give a person a purpose in life. Some conceptions of the future involve a society where drones, robots, and AI do all of the work while the humans relax, but there are risks that the lack of the challenge and feeling of productively contributing to society will be harmful (see some considerations in the chapter "The Future").

Drones and other forms of automation will create, eliminate, and alter a number of jobs. One study has predicted that up to 47% of jobs in the

United States are at risk of being automated – either by robots, software, or algorithms (Frey & Osborne, 2017). In New York city, the introduction of the Uber "ride sharing" app led to a rapid increase in suicides by cab drivers; their livelihoods and futures had been abruptly taken away by this technological disruption (Siemaszko, 2018). In Denmark, it is predicted that there will be 10,000 fewer young, skilled workers by 2035 (Jensen, 2022); young people are pursuing higher education and knowledge work rather than practical trades.

Most robots and drones are designed to reduce labor costs, meaning that they actively participate in the realization of this prediction. If correct, the economic and social impacts will be severe and widespread. In countries with a high level of social security – such as Denmark – costs to support all the unemployed people would sky-rocket. In countries without social protection – such as Sierra Leone (discussed later) – high levels of unemployment could increase poverty and unrest, with the poorest people being the most vulnerable. Changes in the workforce are happening constantly, but what could make this change different is the speed with which it could take hold, making it hard to put policies in place – such as re-training programs – to protect people.

An alternative to the "automate everything to save money" approach is to design for meaningful human work. Meaningful work is that which one finds important and valuable, and which can cultivate competence or even expertise. Lots of empirical data have been collected over the years about what makes a job meaningful; these include having an interesting job, and having a good relationship with management (Sousa-Poza & Sousa-Poza, 2000). Therefore, in designing new technology, we should aim to cultivate stimulating tasks for the human workers and consider how they can have a good relationship with their manager. In some cases, the manager (or at least a system that support management) is already an algorithm – like Amazon warehouse employees whose productivity targets are generated by software (Gerdes, 2022). Philosophers have long critiqued the way technology can be used to exploit and remove power from the working-class – see, for example, the chapter about Marxism which details the struggle of the worker and their "alienation" under exploitative technology (Hansen, 2020). VSD is an opportunity to make technology that enhances rather than detracts from a meaningful life.

Designing for meaningful human work will quickly redefine what role robots play, and which role humans play. In the drone domain, the newly formed job of drone pilot provides an example of what could be considered not-so-meaningful work: during autonomous or pre-programmed flights, the drone "pilot" is tasked with monitoring the drone's location and should be ready to take control in an emergency situation. The result is a job that will be for the most part boring – that is, monitoring the drone's flight via its location on a screen – with intermittent periods of high alertness and stress should a high-risk situation emerge or an emergency take place. If something does go wrong, the pilot is the one that is held responsible.

Drones can be imbued with various levels of autonomy, and choosing the appropriate one is a critical part of the design task, especially when it comes to the work humans will perform compared with what the system will do. In one model, ten levels of autonomy have been identified (see Table 1 in Parasuraman, Sheridan, and Wickens (2000)) ranging from a system that provides no assistance (humans make all decisions), and the system making all decisions automatically, ignoring the human.

During normal flight operations, the prototype drone is at a low level of autonomy on this scale. The system could notify the pilot if, for example, the drone is entering a geo-fenced area such as an airport. Or, the system could operate at a higher level of autonomy in emergency situations, taking over control if the pilot does not override within, say, 15 seconds. Here there is a value conflict between that of autonomy of the pilot to make a good decision, and the value of security; value conflicts are addressed later (see "Value Conflicts").

The prototype healthcare drone is set up to test the hypothesis that actively piloting the drone will lead to more meaningful work. Instead of flying pre-programmed routes, the drone is actively flown by the remote pilot (see Figure 2.2). There is some low-level autonomy, including a geo-fence, which prevents the drone from flying too far off course, too high, or too low – but otherwise, the pilot is controlling the drone in real time.

This approach cultivates the pilot's skills and may keep them more actively engaged during the flight. Humans are very capable at path planning and in handling unexpected situations that may arise. The pilot would be responsible for ensuring the blood sample cargo (which carries the DNA of patients) is safe, avoiding flying over people, looking out for birds, monitoring the weather conditions, and so on. Empirical studies (taking place in the social phase of VSD) can be used to determine if this type of work is too stressful, or perhaps under-stimulating and boring (Fisher, 1991). The drone pilot could be situated in one of the hospitals, making them an integrated part of the healthcare team which has been shown to enhance worker satisfaction (Sousa-Poza & Sousa-Poza, 2000).

In many cases, drones are purported to be the solution to the "three d's": dull, dirty, and dangerous work. It should be noted that these aims are normative (see "Normative Ethics") – they say something about the way thing *should* be, which has ethical implications. Specifically, they say that dull, dirty, and dangerous work is bad and should be avoided. This might seem like an uncontroversial position to take and perhaps most engineers would accept it at face value. However – like most situations with an ethical component – things are more complicated, and there are arguments for why the three d's are not always undesirable.

First – although the healthcare drone was designed to reduce boredom – there are potential benefits to it.

> The state of boredom (i.e., the transitory and nonpathological experience of boredom) should be understood to be a regulatory psychological state that has the capacity to promote our well-being by contributing to personal growth and to the construction (or reconstruction) of a meaningful life.
>
> (Elpidorou, 2018)

The somewhat uncomfortable experience of becoming bored – perhaps from under-stimulation or feeling uninspired – prompts one to change their state by moving, changing location, or thinking creativity. It could be discussed if the state of boredom is a positive thing at work, where people are somewhat forced to deal with it in order to make a living, rather than boredom in their private lives (for example, having a smartphone at one's fingertips makes boredom a thing of the past), but the avoidance of boredom by design is normative in nature. Do we want to live in a world where we are constantly stimulated?

There are many dirty jobs that people find meaningful. One anecdote that provides evidence to support this claim is the popular U.S. Television series *Dirty Jobs* (Dirty Jobs, 2023). In the show, the host Mike Rowe acts as apprentice on dirty jobs, including garbage collection, coal miner, and sheep castrator. What Rowe often finds is work that is surprisingly challenging, and workers that are satisfied with performing a needed task, which most others would avoid since "somebody's gotta do it". If engineers continue to "clean up" all the dirty jobs, what will the overall impact on society be? There is also a subtext that blue-collar jobs *are* valuable to society, and that we should give them – and the people that do them – a bit more respect. Given that cardiovascular disease is the number one cause of death worldwide ("List of causes of death by rate," 2022), by creating more white-collar desk jobs, are we not contributing to the lack of physical activity that is killing so many people?

Lastly, and probably the most contentious of the three d's is dangerous work. While it would be wrong to create a dangerous job (especially with that explicit aim!) it is worth discussing the significance danger has in society. Danger – when taken on in a deliberative manner – can allow one to cultivate the virtue of courage (see "Virtue Ethics"). The presence of danger is necessary for one to become a hero. It has been argued that the use of military drones takes away a soldier's ability to act courageously. A military drone pilot may exhibit proficiency and even expertise in the operation of the remote aircraft, but it would be difficult to argue that they exhibit bravery since there is no risk of physical harm (although a real risk to psychological harm – see Dual Use). What would happen if all danger were eliminated from our lives? How could we show courage? Who would our heroes be?

2.1.7 Justice

Justice deals with the equitable distribution of benefits and harms upon a population (Floridi et al., 2018), including impacts on the basic rights, dignity, and welfare of individuals or groups (Vallor, 2016). Justice includes fairness – the quality of treating people equally, and responsibility – accountability for one's actions (Vallor, 2016). Technologies do not benefit or burden all people and groups equally, so issues of justice are important in their design and implementation. Of particular concern are vulnerable groups and individuals – those with limited power. Technology should benefit them as well – or at a minimum, be acutely aware of and minimize potential harm to these stakeholders.

In the case of the Danish healthcare drone, justice is at the core of the decision to build the drone or not, and, if it should be built, how to build it. Residents of the island of Ærø – especially those who are elderly and are more likely to become sick – stand to benefit from this healthcare drone. They may no longer have to take the ferry to Svendborg for a doctor's visit (which takes most of the day), or may not have to be quarantined as long if urgent blood samples can be transported more rapidly by drone. Residents of Svendborg, where the drone will land and where the samples will be analyzed, will experience some harms from the operation. The drone's presence constitutes a risk to safety, as well as potential risks to security, privacy, and calmness. Drone pilots, maintenance personnel, researchers, and companies will benefit from healthcare drones, while the couriers that perform the task of caring for and transporting medical samples will find their jobs at risk. Pilots as well as wildlife on the drone's route, such as birds, could be negatively impacted. Building drones requires the use of natural resources with a related human and environmental impact. Every stakeholder will experience the drone differently, adding to the complexity of designing for justice. Does the drone constitute a fair distribution of benefits and harms? Taking a utilitarian standpoint (see "Consequentialism"), do the benefits to sick people on Ærø and the drone industry outweigh the risks to people in Svendborg, the couriers, and the environment?

A related matter concerns the fairness of the Danish government's move to centralize healthcare in the first place; this is likely aimed at cutting costs – which is a benefit to Danish citizens – but could negatively impact those living in rural areas where smaller local hospitals are being shut down. Using drones to transport medical samples from rural clinics to larger hospitals on a routine basis supports this centralization of healthcare – with all of its complexities and implications for justice. Again, a key decision in the design of the healthcare drone is its purpose and capabilities, and the prototype drone's design – which supports the emergency transportation of a few urgent samples – aims to minimize risks while giving important benefits to rural residents.

It is possible that "good" drones – which are able to increase justice – will lead to the building of infrastructure (such as 5G towers pointing toward the sky) and public acceptance. This could be the basis for an invasion of drones with much less admirable purposes – where the benefits and risks are much more unevenly distributed such as coffee delivery or advertising. This calls for a long-term perspective on drone use in general, and thinking critically about the future (see "The Future").

2.1.8 Environmental Sustainability

Environmental sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (*Report of the World Commission on Environment and Development: Our Common Future*, 1987). Environmental sustainability can refer to minimizing harm to the natural world, as well as supporting its thriving and working to rebuild prior harms. Sustainability shows respect for people of the future by not encroaching on their livelihoods, and it shows respect for materials and the work that went into cultivating, harvesting, and manufacturing them.

Drones could potentially benefit, as well as harm, the environment. For example, in some cases drones use less energy than other means of transportation (Stolaroff et al., 2018) and are therefore less harmful to the environment. However, they could also do direct and indirect environmental damage. In California, a hobby drone pilot was illegally flying over a nature reserve, filming a huge flock of nesting birds (Wisckol, 2021) . The drone crashed, scaring away an estimated 2,000 birds, and leaving their eggs abandoned. This was the largest abandonment in 20 years, according to the reserve manager.

When developing technology, it is important to consider not only the use of the product but its entire lifecycle. A product's lifecycle can be broken into four main phases (Howarth & Hadfield, 2006), with each phase having an environmental impact along with having associated social and ethical implications:

1 Raw materials
2 Manufacturing
3 Use
4 End-of-life/disposal

In the case of drones, the process starts with extraction of raw materials from the earth. Drones are made of some rare and valuable materials; for the electrical components: lithium for the batteries, cobalt and neodymium for the electric motors, and gold for the traces in the circuit boards. These extraction processes are often environmentally damaging, involve unfair labor practices, and take advantage of people in poor countries. For example, the mining of cobalt – a critical rare earth metal used in electric motors and lithium batteries – in the Congo has been called modern slavery by experts (Siddarth, 2022).

Drone frames are often made of carbon fiber reinforced epoxy (a type of high-strength thermosetting plastic). Although very high in stiffness and low in weight, carbon fibers require large amounts of energy to form, which generates the greenhouse gas $CO_{2,}$ and the fibers can be made from petroleum, a non-renewable resource. However, such high-tech materials can produce lighter weight structures than alternative materials, which could reduce the lifecycle impact during the use phase.

An analysis of the environmental impact of the Danish healthcare drone found that the carbon fiber structure was responsible for the largest amount of CO_2X (carbon dioxide-equivalent) due to the extraction and production of the raw materials (Iversen, Birkved, & Cawthorne, 2020). The electronic components were the second most impactful parts of the drone; these parts should be in focus when creating more environmentally sustainable drones. Subsequent work has identified promising alternatives, including high-performance structures made of wood (Cawthorne & Iversen, 2021), and the re-use of electronic "waste" – such as old electric drill motors and batteries, and old smartphones – to power and control a drone (see "The Sierra Leone Educational Drone").

There are environmental and human health hazards in the manufacture of drones. In particular, the epoxy resin used to stabilize the carbon fibers, although very strong and durable, is hazardous to human health and aquatic life. It was found that changing from an epoxy-based composite to a thermoplastic-based one in the prototype healthcare drone's frame reduced most health impacts by a factor of ten (Iversen et al., 2020).

In the use phase, the drone is operated and, ideally, performs its intended task as designed. Some potential benefits and risks of drones on the environment during use have been discussed previously. Defining the task the drone should perform, and being able to compare it in a fair way to alternative methods is a challenge within environmental impact assessment. For example, in the case of the prototype healthcare drone, determining the scope of the analysis – should it include only direct impacts, secondary impacts/impacts to suppliers, etc., and defining the functional unit – the unit of analysis – 2 samples or 20 samples – has a massive impact on the results of the analysis. For carrying heavy and low-value cargo, drones often compare poorly with alternatives such as ground or sea transport; for carrying lightweight, high-value, urgent cargo, drones will usually perform very well (Iversen et al., 2020). This means that the study can be manipulated to make either technology look more appealing simply by defining the functional unit in a certain way.

No products last forever, and eventually they reach their end-of-life: where they are no longer functional or are discarded for other reasons (i.e. they are no longer desirable). Most drones will not have a particularly long lifespan – they will crash, wear out, or become outdated within a few years – so it makes sense to design them with this lifespan in mind. Smaller drones powered by electric motors constitute a new type of electronic waste, which is deemed hazardous and is costly and complex to deal with. Drones made of carbon fiber and epoxy cannot be recycled; in Denmark, they will typically be burned for energy at the end of their service life. But there are many more sustainable alternatives: using materials which can be recycled, designing for disassembly, the use of modular components which eases repair, and design for re-use or up-cycling. These approaches show respect for nature and for the people that built them.

While the environmental impacts of drones can be negative, it is also possible to pursue drone technologies that repair and enhance the natural environment. For example, drones are being used to plant trees in Canada ("Flash Forest Drones to Plant 40,000 Trees a Month in Canada," 2020), monitor porpoises in Denmark ("Porpoises in surprisingly advanced group hunting – drones reveal group hunting (translated from Danish)," 2021), and to study bats in the wild (Docherty, 2022). It should be noted that the above examples have social and ethical implications themselves; tree planting in Canada has previously been done by young people and seasonal workers who must overcome the rugged conditions, but earn money and directly experience nature. A value-sensitive design approach takes into consideration both the negative and the positive impacts of a technology – on the environment and beyond – and aims to give a holistic assessment of these impacts.

2.1.9 Trust

Trust is the willingness of one to be vulnerable to others, with the hope that they will respond in good faith (McLeod, 2020). Trust has a temporal dimension – it can be built up over time, and can be broken if transgressed. Generalized trust is that which one has toward society at large, while particularized trust is that which one has toward specific individuals.

In the context of technological development, trust, mistrust, or over-trust are important characteristic of products or systems. Usually, the aim of technology developers is to entice people to trust the technology – for example, for the public to trust the Danish healthcare drone. Reliability is an important consideration with respect to trust – if a system is reliable, it will perform as expected consistently, and thereby (over time) earn peoples' trust. Small drones are quite unreliable, with one study estimating the mean time between failure (MTBF) of hobby drones under 250 grams to be every six minutes (la Cour-Harbo, 2017). Larger drones are much more reliable; for example, the 26 kg Boeing/Insitu Scan Eagle military drone has flown 1.2 million flight hours with "99% mission readiness" ("ScanEagle," 2023). (A note about dual-use: this now military reconnaissance drone was originally designed for aerial scouting of tuna ("Tuna Fishing to Tactical Observation: ScanEagle UAS," 2016)).

Sometimes, developers use manipulation to enhance users' trust; arguably, the use of anthropomorphism – giving a system human-like characteristics – is a way to engender trust in the system by taking advantage of humans' propensity to connect with things that have human-like (or animal-like, i.e. zoomorphic) characteristics. The Boston Dynamics dog-like "Spot" robot (here, an example of military-civil dual-use, originally being developed for military operations) utilizes this strategy, even being given a dog-like name ("Spot," 2023).

Although anthropomorphism is a less-used strategy in drone design, one study tested drone designs based on cartoon characters (Pakrasi, Chakraborty, & LaViers, 2018). One was given the color, eyes, and movements of Tigger (orange, upward-turned half-moon, high-frequency oscillation or "bouncy" movements), the other of Eyeore (blue, down-turned half-moon, low-frequency oscillation or "dragging" movements) in an attempt to "engender likability…acceptance, and trust".

Those exposed to a piece of technology might mistrust it – believe that they cannot be vulnerable to the system and that it will not act in good faith. In the drone case, the public might suspect the drone will surveil them, or worry that it could crash into and injure them. The organization or persons that have developed or that are operating a system will influence the level of trust. In Denmark, the state emergency services are more trusted than private hobby drone pilots (Bajde, Woerman, et al., 2017). A risk in technological development is that the system may experience over-trust: where the system's capabilities are over-estimated. In one experiment, participants followed the instructions of an emergency evacuation robot and entered a smoke-filled room (Robinette, Li, Allen, Howard, & Wagner, 2016). When asked why, they responded that they thought the robot had sensors throughout the building even though there was no indication it had this capability.

Ethically informed, value-sensitive design should not utilize manipulation to gain un-earned trust. It should allow users to opt-out of being exposed to the technology if they wish, and require them to actively accept the exposure (i.e. via informed consent). The system should be designed in a way such that the actual capabilities are evident – not being overstated or understated. One strategy in which to do this is through explicability (see "Explicability").

Taking the Danish healthcare drone case into consideration, trust is a critical aspect of the current and proposed processes. Although the job of medical courier is at first glance simple, there are important aspects of trust in the assignment – the courier takes physical care of a potential biohazard in the form of blood samples and is entrusted with the personal data and DNA of multiple patients while transporting them from Ærø to Svendborg. With the drone, it is now the drone pilot who should act as courier, and *remotely* care for the important cargo. The livestreaming video of the cargo bay, the locking mechanism, and the biohazard markings all aid the pilot in this task, but they do not have direct physical control over the samples.

The healthcare drone's small size – although more inherently safe than a larger drone – makes it more vulnerable to bad weather. And although the drone has redundant servos on the primary flight surfaces – two for the elevator and two for the rudder – it is small and therefore unable to carry as many redundant systems as a larger drone – dual motors, or a parachute for example. If the drone were to fail often, trust in the system, and in the institutions operating it, could be reduced.

2.1.10 Explicability

Explicability is the ability for a system to be easily understood (Cawthorne & Frederiksen, 2020). Explicability includes two related concepts: intelligibility, which asks "how does this technology work?" and accountability, which asks "who is responsible for this technology?" Drones are challenged on both of these fronts, and current designs suffer a lot from a lack of explicability. Empirical evidence suggests that people expect there to be a pilot nearby when they see a drone (Bajde, Woerman, et al., 2017). This indicates that they are trying to find out who is responsible for the drone (accountability) and that they do not understand that drones can be operated autonomously or from great distances, so the pilot (if there is one) will not necessarily be known to them.

Multirotors drones are usually symmetrical, making it difficult to discern where the "front" of the drone is or which direction it is flying. To remedy this, drones often have colored lights on them, which may aid the pilot in orienting the drone, but which does not help the outside observer unfamiliar with the lighting configuration. One approach to making multirotor drones more intelligible is to make them *un*symmetrical and make it clear where the sensors are located – these approaches were used in the design of the search and rescue drone (see "The Search and Rescue Drone"). Fixed-wing drones must always fly forward to stay in the air, which makes them less susceptible to this confusion.

Most drones currently available are either white or black, which may be seen as "neutral" colors. But white is very difficult to see against a cloudy sky and is hard to associate with a specific industry or operator. Black drones may be interpreted as threatening, or be associated with military operations. An explicability-enhancing approach is to paint the drone a color that contrasts with the sky, and that is associated with the industry it is a part of.

In Denmark, ambulances are neon yellow with a dark green checker pattern running along the top and bottom edges of the vehicle (see the earlier section on "Context"). The healthcare drone is painted similarly as shown in Figure 2.1 – it is neon yellow with a dark green checker pattern on the front of the wings. This color scheme is widely recognized in Denmark as being associated with healthcare and the ambulance services. The red text on the drone (see Figure 2.1) is written in Danish. The text, translated to English, reads "ambulance", "blood samples", and "camera" (on the tail). Although many people in Denmark understand English, it is most contextually appropriate for a Danish healthcare drone to be labeled with Danish text. Anyone that has traveled to a country where they do not know the language can easily identify with the challenges this creates in understanding one's surroundings.

A study including 110 participants, many of whom live near Danish hospitals, was used to inform the visual and aural (sound) design of the prototype healthcare drone (Cawthorne & Frederiksen, 2020). The study indicated that neon yellow color was most associated with healthcare (compared with red and white, for example). Ninety percent of the respondents found the color of the drone more important than its shape or configuration, showing the importance of this seemingly superficial attribute to the explicability of the system. Participants had a slight preference for an airplane-shaped drone compared with other shapes such as a "plus" shaped quadcopter and twin-fuselage VTOL confirmation, saying that the airplane shape looked safe and like a normal airplane. The study also indicated that informative text and symbols were must-have or attractive attributes, respectively. This prompted the inclusion of the large red text indicating that the drone is a flying ambulance, denoting its cargo (blood samples), and that it carries a camera.

In operation, drones may be hard to see – they are often cruising at 80 meters altitude or higher – so a smartphone app (see Figure 2.3) has been proposed, which allows citizens increased visibility of drone flights. They are notified via push or pull notifications of the drone's presence (via its GPS) and can praise or complain about the flight via the "comment" feature. They may opt out of being overflown through the "avoid me" function. Regarding this approach, a heuristic ("rule of thumb") is that if more than 10% of a population are strongly against a technology, then it should not be used (or changed in significant ways to address concerns) (Friedman & Hendry, 2019). However, it has been argued that an adamant minority should not be able to halt activities that could be beneficial to wider society (Van de Poel, 2016). With the envisioned prototype drone system, protection of the public and those that are not part of the operation but who are exposed to the drone are prioritized. The app gives information about the drone pilot's identity and location. This has implications to the pilot's privacy but serves to shift the balance of power from the often-anonymous drone operator back to the public (Figure 2.3).

Using a smartphones app to relay crucial information may exacerbate the digital divide – the division between those that are comfortable with IT

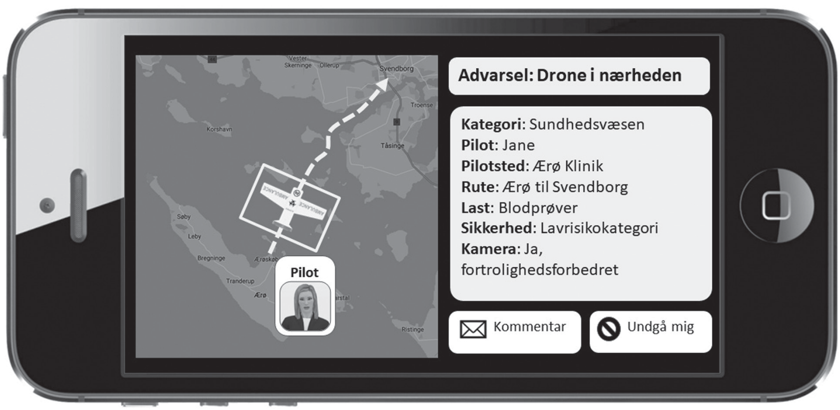

Figure 2.3 Concept of an explicability-enhancing smartphone app. The app notifies citizens near the drone's flight path of its presence and its purpose – supporting intelligibility. It gives information about the pilot – supporting accountability. The app would be deployed in Denmark, so the text is in Danish. It reads (from top to bottom) "Notice: drone in the area. Category: healthcare drone, Pilot: Jane Doe, Pilot location: Ærø clinic, Route: Ærø to Svendborg, Cargo: blood sample, Safety: low risk, Camera: yes, privacy preserving. Comment. Avoid me".

Source: Graphic by the author.

and those that are not. In Denmark, it is said that around 80% of the population are IT-savvy, but perhaps 20% make up the "digital underclass" (Sorgenfri, 2022). They may lack the equipment, experience, or desire to embrace digitization, preferring analogue and in-person communications. Adding another app will only support this divide; therefore, analogue means of communicating the drone's purpose and operator – including its color, markings, and text – are preferred, and analogue or alternative means of commenting on and opting out of being overflown by drones should be established.

2.1.11 Dual-use

Dual-use refers to a technology's ability to be utilized in both civilian and military contexts (Novitzky, Kokkeler, & Verbeek, 2018). Critically, there is a lot of gray area between civil and military uses: private security, policing, and border control have elements of both civil and military operations. Common examples of dual-use technologies include the internet and GPS, which were both developed by the military but are now in service in the civil sphere. Civil technologies are often utilized for military use as well, including the earliest aircraft developed by the Wright Brothers ("Wright Brothers," 2022) and Alberto Santos-Dumont ("Alberto Santos-Dumont," 2022). Some reported that Santos-Dumont's death by suicide had been caused by distress because the airplane was being used to kill[2]: "Why did I make this invention which, instead of contributing to the love between men, turns into a cursed weapon of war?"

It has been argued from a virtue ethics perspective that the impacts of war should not be avoided, that in order to cultivate courage and justice that each of us must "work tirelessly to prevent and oppose war, or to courageously accept some share of the devastation and irrevocable loss that our failure to prevent war brings about" (Vallor, 2016). Courage and justice are not virtues that are easily enhanced with the use of remote and often asymmetrical technologies such as drones. And some of the assumed benefits – for example, that drone pilots would not suffer harm – has been disproven as they experience post-traumatic stress disorder (PTSD) at the same rate as front-line soldiers (McCammon, 2017). Investment in war demonstrates that one assumes the future will be one of conflict; what would investment in technologies of peace look like? What are technologies of peace (Vallor, 2016)?

The Danish healthcare drone could conceivably be used in a military context – for example, to send medical samples from the frontlines back to base for analysis. However, the bright paintjob and markings – although easy to alter – would draw attention and make it vulnerable to attack. Its low-resolution camera would make it difficult for the pilot to discern friend from foe, and if attacked it would have low survivability – a useful attribute for a military technology but not for a civil drone that has been accepted by the public (Van Wynsberghe & Nagenborg, 2016). Its limited range and small payload capacity render it less useful than alternative approaches. The inflexibility of the cargo bay, and the pre-flight scan would limit its usefulness in carrying a bomb or sensors useful in a military context. Still, some argue that providing healthcare – be it in a civil or military context – is a responsible and morally defensible activity to support (see chapter 9 "Robots in War and at Home" in Vallor (2016)).

2.1.12 Misuse

Design consists of the development of a technology, together with a use plan (see "Use Plan"). However, no matter how well (or poorly) developed the *intended* use plan may be, there can still be a lot of leeway for misuse – the harmful use of a technology, often in a way not intended by its designer(s). More generally, these other uses that are not necessarily harmful have been called *creative* use (Houkes, 2008). Creative use points out that, often, technologies are not used exactly in the ways which were intended and highlights the user's agency and sometimes even ingenuity in the act of using technology. Most authors did not intend their books to elevate a computer monitor to a better working height, or as a drink coaster to protect a cherished coffee table, but sometimes this is how they are creatively put into service by their users.

Here, the concept of multistability is useful; it states that the way technology alters interactions or gives capabilities ("mediation") depends on (1) the technological design, (2) the intentions of the designer, and (3) the user's interpretation and appropriation (Verbeek, 2006). It is only through this complex interplay – influenced by social aspects including culture, and situated in a particular context – that gives rise to a particular outcome. Therefore, designers and engineers have a significant amount of power and influence over the outcome, but do not act alone. And in order to act responsibly, they should be aware of and plan for at least some of the most likely misuses of their designs.

However, not everyone wants to take such proactive responsibility. Companies will often attempt to make one-size-fits-all or universal products – the platform approach, where technologies are positioned as flexible multi-tools rather than contextually situated and task-specific (Gillespie, 2010). For example, social media providers such as YouTube and Facebook describe themselves as distribution platforms for user-generated content. This positioning allows them to disavow responsibility for the use of their products or services, placing the accountability solely on the user.

Drone companies do the same, claiming to offer a *flying* platform (SkyWatch, 2022), which the user can operate as they wish. A generic technological approach may make sense when considering economies of scale – it could initially cost less to develop one model of a drone rather than multiple models for different markets or with more focused capabilities. However, this approach is challenged in light of the various contexts and use plans (discussed in the section on Use plan) that are possible. It is especially problematic for technologies that can easily be transferred, such as drones and mobile phones, compared with buildings and other fixed infrastructure.

2.2 The Social Phase

In the social phase of VSD, the interaction of people with technology is taken into consideration. This includes contextual aspects (i.e. location, culture), the use plan, and impacted stakeholders. These considerations are illuminated through empirical investigations. A number of important factors are impacted by context – some are technical, such as the operating temperature of a drone (Denmark versus Africa), and some are social, such as the public perception of drones. Ignoring contextual issues will at least lead to a lower-performing product, and in a worst-case scenario a technology that will be rejected by society.

2.2.1 Context

Denmark is a small, flat country with a population of 6 million people ("Denmark," 2022). Denmark consists of a peninsula north of Germany (Jylland), along with two large islands (Sjælland and Fyn). In addition to the large islands – which are connected by bridges to the mainland – there are many smaller islands, which can be less accessible, but where people live. This includes the island of Ærø, which has a population of 6,000 inhabitants ("Ærø," 2022).

The citizens of Denmark are affluent – GDP per capita is 68,000 Euro ("Denmark," 2022) – and enjoy a high level of safety, security, and healthcare. The average life expectancy at birth is 81 years (Life Expectancy at Birth, 2020), and there are on average 3 traffic deaths per 100,000 people per year ("Estimated road traffic death rate (per 100,000 population)," 2019).

Danish is the official language, and over 80% of the population also speak English ("Languages of Denmark," 2022). The island of Ærø is a popular tourist destination in the summer and is known as a peaceful place to live which attracts many elderly and retired people.

Over the past few years, the Danish healthcare system has been undergoing major changes – many of the smaller regional hospitals have been closed, and the funds have been redistributed to create or build up "super-hospitals" in the larger cities. Drones could provide logistics, which support this move to super-hospitals. Importantly, drones might preclude an in-person visit to a hospital. This has advantages in terms of ease-of-use: the patient does not have to travel to the super-hospital. But there are critical differences between an in-person visit compared with a remote blood sample result, the implications of which were discussed in the ethics phase (see "The Ethical").

2.2.2 Use Plan

Engineers and designers do not just create products – they also design a use plan for those products (Houkes, 2008). The same is true in drone design, where the use plan is either made explicit – in a user manual, for example – or implicitly, through design affordances and capabilities. The use plan may be developed based on testing out certain uses, and/or by envisioning uses. Sometimes, this process will even consider "creative" or misuses. The use plan may assume a certain context of use, or ignore contextual issues and consider the system a universal platform (see "Misuse").

The Danish healthcare drone is developed to deliver urgent blood samples from smaller islands to a major hospital for analysis; the prototype was designed to fly from the regional hospital on the island of Ærø to the larger "super-hospital" in Svendborg – a direct distance of 27 km. The regional hospital can be seen in Figure 2.4.

Currently, batches of samples are shipped via a courier a few times a day in a van that then takes the ferry. There is ferry service from the island approximately every two hours between 4:00 and 20:00 and crossing times are 75 minutes (Ærøfærgerne, 2022).

The high-level use plan for the Danish healthcare drone is envisioned as follows:

- The drone acts as a supplement to the current courier infrastructure, which continues as normal.
- The drone pilot is located at Svendborg hospital and is part of the healthcare team.
- Urgent medical samples are transported by courier as a backup should the drone fail.
- Samples are loaded into the cargo bay of the drone.
- The RFID tags on the samples are verified by the drone system.
- The drone is launched from the back yard of the Ærø hospital.
- The drone is flown mostly manually (with a low level of autonomy) from Ærø to the Svendborg hospital.
- The drone lands on the roof of the Svendborg hospital via a net.

Figure 2.4 The hospital at Ærø island where the healthcare drone would fly from (top). Behind the hospital is a grassy lawn that looks out to the ocean, and where a drone launcher could be set up (bottom).

Source: Images by the author.

- The medical samples are taken out of the drone and analyzed.
- The drone is transported back to Ærø via the normal van courier.

It should be noted that, although this is the use plan intended by the designer, there is nothing to guarantee that this is in fact how it will be used. Many aspects mentioned above are operational or organizational and could be carried out in a multitude of ways. For example, there is nothing (other than its relatively small payload capacity) preventing the drone from being used only to supplement existing healthcare infrastructure. It is also possible that in practice the drone pilot will be located at an airport or co-located with other drone pilots far away from the healthcare context. "Creative" and "misuses" of the drone are also possible and are discussed in the chapter on misuse (see Misuse). The design does of course make some use plans easier; for example, as designed the drone cannot be flown back to Ærø from Svendborg as it would not have a net to land in.

The use plan perspective also highlights that the drone itself is only a small – although important – part of the drone system and infrastructure; it relies on satellites, GPS, and launching and landing apparatus, among others. The materiality of high-tech systems, such as "the cloud", are often made or appear invisible (Borning, Friedman, & Logler, 2020) making them less understandable. These considerations are taken up in the section on Explicability.

2.2.3 Stakeholders

Stakeholders are those that are impacted by a technology (Friedman & Hendry, 2019). They can be divided into direct stakeholders – those that interact directly with a technology (users, for example), and indirect stakeholders – those that, although they do not interact directly with the technology, are still indirectly impacted. A useful approach to identifying impacted stakeholders is to baseline the current process and compare it to the new process with the technology in place (see Table 1 in Van Wynsberghe (2016)). Stakeholder is a *role* rather than an individual or group: for example, a drone researcher when at work is a direct stakeholder in drone development. But when a drone flies over the researcher on their way home from work, they are an indirect stakeholder to that technology. Stakeholders need not be human either; for example, non-human animals and the natural environment (i.e. lakes, glaciers, the atmosphere) are often impacted by technologies. It is an ongoing methodological challenge to identify the best way to understand the values of stakeholders that we cannot directly speak with such as non-human animals and future generations of humans that are not born yet. One approach is to identify spokespersons for these groups, such as Danish Ornithological Society on behalf of birds in Denmark (DOF, 2022).

Identifying stakeholders in a robust way is not easy (see some important critiques to VSD, including stakeholder identification in Manders-Huits (2011)). Indirect stakeholders are particularly challenging to identify as they are, by definition, at some distance from the technology. Our world is incredibly interconnected, and a technology used on the other side of the planet may impact us in real ways. For example, any technology which generates CO_2 impacts us all as it contributes in some small way to climate change. Therefore, it is important to be inclusive, while balancing the practical limitation that it is impossible to engage everyone. If stakeholders are omitted, it is important to justify this omission, or at least acknowledge it.

VSD differs from traditional design in that the values of many more stakeholders are considered during the design phase – including those that might be negatively impacted. Companies usually focus almost exclusively on their customers, and perhaps secondarily on the end-users of their products. This can lead to a narrow and short-term focus on a few powerful stakeholders. This means that the values of the less powerful are either ignored or forgotten completely, and longer-term considerations – such as the more far-reaching impacts on society, the environment, and future generations – are omitted.

It should be noted that *only* listening to stakeholders could lead to the naturalistic fallacy – where what people *want* is confused with what *should be done* (i.e. what is morally right) (Manders-Huits, 2011). For example, users might like an app which makes it easier to download stolen films online, but which is morally problematic. The ethical phase of VSD and engagement of various stakeholders helps to avoid the naturalistic fallacy.

Introduction of the Danish healthcare drone in the healthcare system would have an impact on a multitude of different stakeholders. Direct stakeholders include patients and staff at the Ærø hospital, staff at the Svendborg hospital, the couriers currently tasked with transporting medical samples from Ærø to Svendborg, wildlife including birds in the area, pilots and passengers flying in aircraft near the drone operation, the drone pilots, drone developers, and drone manufacturers. Some indirect stakeholders are citizens and homeowners that are overflown by the drone, police and other emergency services, and the Danish military.

2.2.4 Empirical Investigation

Empirical methods are experimental methods often conducted in the field or with the participation of human subjects. Empirical studies can be highly useful; for example, in testing technological specifications with stakeholders and in determining which values different stakeholders hold. These methods are expanded in the section on the social phase methods.

Empirical evidence indicates that, in general, the Danish population is open to the use of drones for "good" purposes by "trustworthy" actors. These good purposes include firefighting and other emergency services. Public service organizations are considered trustworthy, as are professional users; hobbyists are less trusted (Bajde, Bruun, et al., 2017). This openness to drones in Denmark can be contrasted with their perception in other contexts – for example, in areas where drones have been used in spying, military, or terrorist operations. The humanitarian UAV code of conduct recommends that even “good” drones not be used in conflict zones (Bothner, Chakraborty, Khan, & Howarth, 2021). In civil applications where drone deliveries have been tested, residents have in some cases banded together to fight against the annoyance the drone’s noise and presence causes (“Bonython Against Drones,” 2023). A common opinion is that the level of disturbance should not exceed the benefits the drone brings (Bajde, Bruun, et al., 2017) – a utilitarian normative perspective (see Consequentialism). Experiencing a high level of disturbance so your neighbor can get their coffee delivered faster is not acceptable, but a healthcare drone – or flying ambulance – carrying urgent medical samples flying over one’s property might be ok.

2.3 The Technological Phase

In the technological phase of VSD, the considerations from the ethical phase and the social phase are used to inform design requirements, product specifications, and ultimately to build value-sensitive technology. In this section, the technological specifications and resulting performance of the prototype Danish healthcare drone are presented.[3]

2.3.1 Size and Configuration

The prototype Danish healthcare drone is a fixed-wing type with a conventional aircraft configuration: the main wing is in front and the horizontal and vertical tails are in the rear. It has a 1-meter wingspan, is 1.15 meters in length, 0.26 meters tall, and weighs 1.4 kg; the body is 15-cm wide.

2.3.2 Materials

The aerodynamic surfaces are made of extruded polystyrene foam supported by carbon fiber tubes and rods; the frame is a carbon fiber and thermoplastic sandwich with an end-grain balsawood core. Polylactic acid (PLA) plastic fittings hold the carbon fiber tubes and rods to the frame and align the aerodynamic surfaces at the required angles.

2.3.3 Exterior

The exterior of the drone is painted neon yellow with a dark green checker pattern on the front of the wings. Red text on the wings, body, and tail state: “ambulance” (ambulance), “blodprøver” (blood samples), and “kamera” (camera). There is a biohazard symbol at the top and bottom of the drone’s body.

2.3.4 Cargo Bay

At the front of the drone is a clear cargo bay, secured with a solenoid latch. The payload bay has three openings – one that is 7×3×3 cm, and two that are 12×3×3 cm. A RFID (radio frequency identification) reading system is mounted inside the cargo bay.

2.3.5 Power System

The drone is electric powered – it has a 150-watt, 2200 kV brushless motor (Hacker A10-7L (Hacker, 2021)) with a 4.4:1 gearbox turning a 12×8-inch propeller mounted at the back of the aircraft. Two, three-cell lithium-ion battery packs are combined in parallel to produce 12 volts and give 6.9 amp-hours of capacity; these are mounted toward the front of the drone.

2.3.6 Sensors

The camera system – which includes a small raspberry pi computer with a three-axis accelerometer and barometric pressure sensor, along with a raspberry Pi zero camera – is mounted on the top of the vertical tail. A 250 mWatt, 5.8 gHz wireless transmitter broadcasts the video signals. The video feed transmits when the drone is flying, and the resolution of the video varies based on the drone’s altitude from 144 pixels at ground level to 1080 pixels (high definition) above 80 meters.

2.3.7 Control and Autonomy

The drone is steered using two servos for pitch control – one servo for each half of the elevator, and two independent servos are used on the split rudder – one actuating the top of the control surface, the other actuating the bottom.

The drone’s flight controller (the brain of the system, coordinating the power to the motor and inputs to the servos to steer the drone) exhibits a low level of autonomy; it prevents the drone from flying outside the designated flight corridor (a “geo-fence”), and keeps the drone within the minimum and maximum altitudes; otherwise, it is actively controlled by a human pilot from the ground station located at the Ærø hospital.

2.3.8 Support Systems

The drone is operated from a remote ground station (i.e. laptop computer) and the drone's location is monitored via GPS. The drone would be launched from an electromagnetic linear rail, which accelerates the drone to flying speed, deployed from the back yard of the Ærø hospital. A rooftop-mounted net would be used to retrieve the drone at Svendborg hospital.

2.3.9 Summary of Specifications

- Wingspan – 1 m
- Length – 1.15 m
- Height – 0.26 m
- Weight with payload – 1.4 kg
- Power – 150 watts
- Cargo bay size – 7×3×3 cm, 12×3×3 cm, 12×3×3 cm

2.3.10 Performance

The materiality of the prototype drone described above – when used according to a use plan (see "Use Plan") – leads to the following performance characteristics (estimated based on initial flight testing):

- Flight time – 40 min
- Cruise speed – 45 km/h
- Range – 30 km
- Payload – 85 g

2.4 Should This Drone Be Built?

Maybe.

Perhaps the most important questions to be addressed in the ethics of drone design are the meta-questions: should this drone be built? If so, how? If not, why not? This is called the value-sensitive *alternative* approach: there are always alternatives to the suggested technological "solution", and one alternative is to *not* develop the technology at all (Spiekermann, 2015). Sometimes, the argument will be made that "if we don't build it, someone else will". This is, of course, not necessarily the case – especially if engineers refuse to participate – and there are many examples of technologies humans *could* build but have *chosen* not to, including human cloning and laser blinding weapons. In drone design, the VSD alternative approach reminds all involved that sometimes the best drone is the drone that isn't built. If it is decided to go forward with the development, then VSD can help guide the process – the "how" in the initial questions. And a VSD analysis can help to illuminate the reasons why a technology should or should not be built – for example, negative impacts on vulnerable stakeholders or poor distribution of benefits and risks.

The VSD process is not deductive – defining values does not logically lead to a single, best design (Van de Poel, 2013). The prototype Danish healthcare drone is no exception – many alternative embodiments are possible which would support the previously outlined human values. And just because a drone has a privacy-preserving camera system, a clear cargo bay with RFID tag readers, and a gearbox with a slower-turning propeller does not necessarily make it contextually appropriate or aligned with stakeholder values in other contexts.

The prototype drone was used as an experiment to see if/how the technology developed using VSD was different from that developed using a traditional approach. In fact, the Danish HealthDrone project headed by a colleague provided the inspiration for the specific use-case ("HealthDrone (translated from Danish)," 2022). A main difference between the prototype drone and that developed in the HealthDrone project is that the former supports emergency deliveries, while the latter aims at providing routine delivery (Cawthorne & Robbins-Van Wynsberghe, 2019). In this way, both drones – but especially the HealthDrone – facilitate the centralization of Danish healthcare. The prototype drone minimizes the risks placed on the public (i.e. safety, privacy, jobs), while the HealthDrone prioritizes the direct beneficiaries of the drone with large cargo capacity and high levels of flexibility.

The capabilities of the prototype healthcare drone are much different than those of the currently used technology (driving, taking the ferry), making a direct comparison of the two impossible. There is a fundamental difference between visiting a doctor face-to-face rather than giving a sample and having it analyzed remotely – a drone will facilitate the latter. Danish transportation infrastructure, including roads, bridges, and ferries, is well-established and of high quality making the need for alternatives via drone less necessary or appealing. Roads, bridges, and ferries – especially those that do not have tolls – are quite democratic technologies benefiting a broad range of stakeholders when compared with drones. In the distant future, medical drone deliveries could reduce cost and save the Danish taxpayers money (the healthcare system is already quite expensive), but many studies show that drone delivery is still very expensive when compared with existing transportation methods. It is a very different context, but one study found that drone delivery costs in Malawi were 1,800% higher than transport via motorcycle (Phillips et al., 2016).

The prototype healthcare drone appears more justified when used exclusively for emergency situations, there being an important distinction between routine deliveries and those that are lifesaving or extremely time sensitive. The empirical evidence supports drone use in emergencies, and this could improve the health and well-being of people living in remote areas. However, once the infrastructure and public acceptance for "good drones" performing emergency services are established, it will be difficult to hold back the flood of drones for other purposes – with all the associated social and ethical impacts.

In summary, *maybe* this drone should be built. Hopefully, this chapter has justified this conclusion, demonstrated the complexity of the design process, and shown how the design and specifications of this drone will have social and ethical significance. Later, in the methods chapter (see "The Theory, Methodology, and Practice"), it will be shown that it is not just the technology itself with an impact, but also the process by which it is developed and how it is incorporated into society that matters.

Notes

1 The drone's privacy-preserving camera system was developed together with two master's students (Tinggaard & Larsen, 2021).
2 Other reports claim that Santons-Dumont's suicide was due to depression and bipolar disorder.
3 This section is based on the technical development section of my PhD thesis (Cawthorne, 2020).

3 The Search and Rescue Drone

3.1 The Ethical Phase

Search and rescue (SaR) is a complex and urgent undertaking, with a multitude of moral risks and opportunities at stake. The ethical implications of SaR robots and drones have been investigated previously, which provides some basis for the ethical analysis here (Harbers, Greeff, Kruijff-Korbayová, Neerincx, & Hindriks, 2017).

3.1.1 Human Welfare

The prototype search and rescue drone (Figure 3.1) is developed specifically to enhance human welfare by assisting the rescue team in finding, interacting with, and assessing the condition of lost or injured people. The drone could enhance human welfare by helping people in distress – aiding their physical and psychological welfare. The drone could speed up the SaR operation, saving money and thereby increasing material welfare. It could potentially reduce collateral damage to residents' property, such as greenhouses, which are sometimes damaged when helicopters are deployed under the current practice, again increasing material welfare. However, the drone constitutes a significantly different form of search, and engenders different skills than in-person searches. The drone will cost money, and amassing a swarm of such drones could be costly. And the drone will likely be operated in close proximity to a helicopter in a complex environment, which could cause a crash resulting in injury or death.

3.1.2 Safety

As mentioned previously, the prototype SaR drone could both enhance physical welfare and safety in some scenarios, and reduce safety in others. The drone weighs 3.3 kg and has enough kinetic energy in free fall to seriously injure or kill someone. The wooden bumper around the propellers

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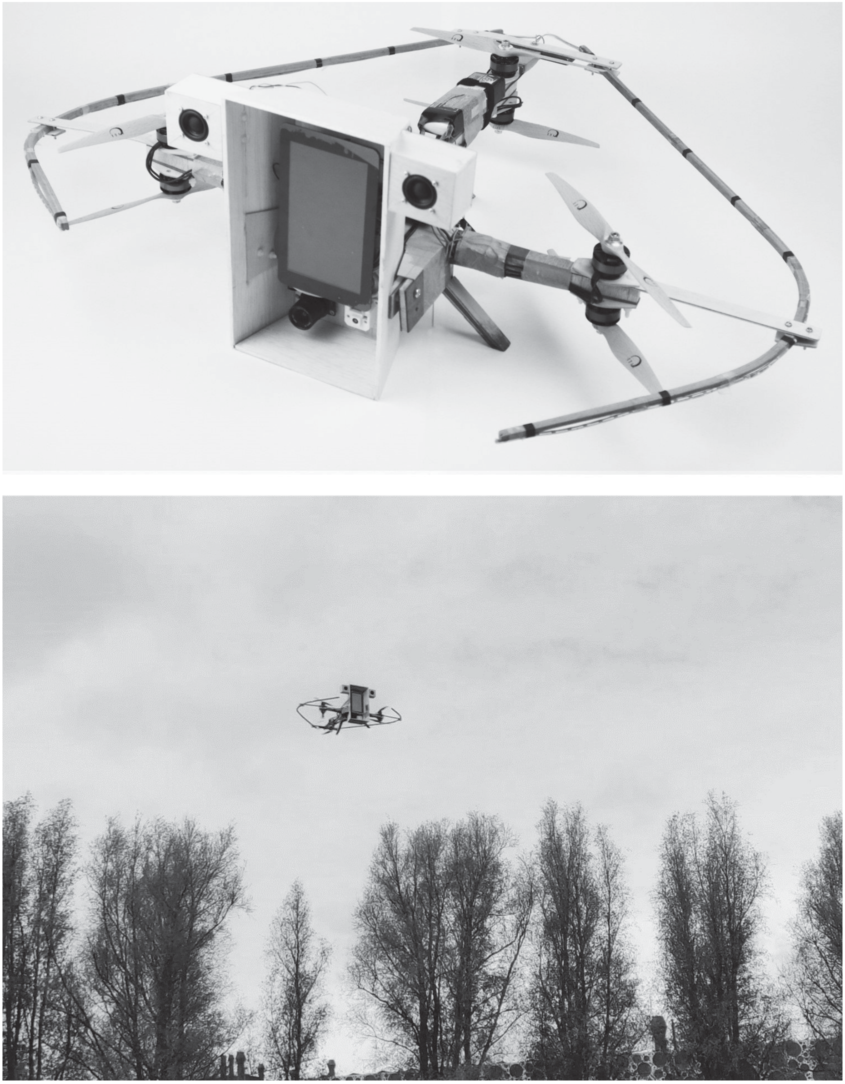

Figure 3.1 The prototype drone is developed for inland search and rescue in Denmark. It has a high-resolution camera and a thermal camera to locate people in distress, and the large screen at the front is a telepresence system, which allows the rescuer and victim to interact directly (top). The prototype drone in flight during testing (bottom).

Source: Top image by the author and bottom image by Andreas Aagaard Asmussen and Nikolaj Pihl Thomsen, used with permission; from Cawthorne and Iversen (2021).

serves mostly to distinguish the extent of the propeller arcs but provide little protection in an impact. The wooden structure could as well be dangerous in a crash, the hard motors will cause damage on impact, and the sharp propellers could cause lacerations. The drone's battery weighs 450 grams, large enough to damage a helicopter's jet engine. The drone is a hexacopter configuration, and with its six motors it will still be able to fly controllably even if one motor fails, which makes it more robust than, for example, a quadcopter drone. Still, it has some single points of failure, such as the battery, which would result in a complete loss of power to all motors. Sometimes, additional safety measures are added onto multirotor drones, such as parachutes or airbags – to reduce their speed and/or sharpness upon impact. These systems typically add around 10% to the weight of the drone and must be triggered reliably to provide any protection.

Helicopters – such as those currently used in SaR operations – are particularly vulnerable to drones: their main lifting and stabilizing tail rotors in particular. In one case, a military helicopter flying at low altitude over the sea off of New York was struck by a hobby drone (Furfaro, Celona, & Musumeci, 2017). Luckily, the drone hit the fuselage and not the rotors, and the helicopter could continue flying. The drone pilot was later identified as parts of the drone containing serial numbers were embedded into the helicopter's fuselage; the drone pilot was unaware it was unlawful to fly in that location. In summary, the prototype drone poses some moderate safety risks.

It is important to remember that safety risks are experienced differently by different stakeholders. SaR personnel acknowledge and accept the higher level of risk that comes along with their jobs (i.e. informed consent). But they still choose to perform this task, which cultivates virtues such as courage, empathy, and care (see the section on "Virtue Ethics"). In contrast, victims – although they could display courage, empathy, and care – do not know beforehand that they will become lost or in need of rescue and have not accepted the elevated risk. The same is true of citizens that may be nearby a SaR operation.

3.1.3 Privacy

Data is extremely useful in a SaR scenario, but this data can create risks to privacy. Victims are particularly vulnerable in a SaR operation – they could be disoriented, injured, or even dead – making the preservation of their privacy and dignity critical. If drone video of a victim is freely accessible, their family could learn about their distress in the news before being notified by the authorities (Harbers et al., 2017). As well, many uninvolved people and private properties could be surveilled during the search and rescue operation. Police or other parties that wanted to monitor a

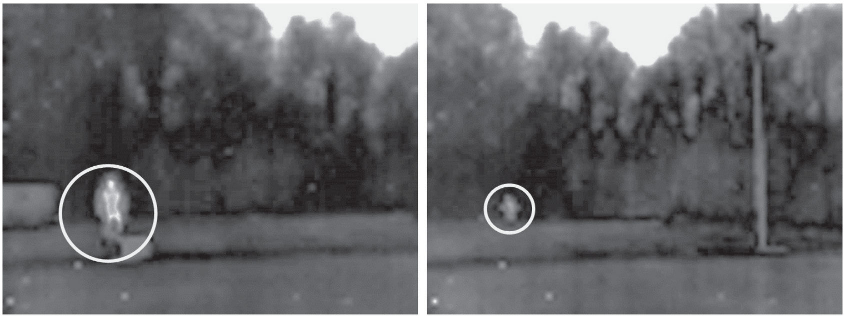

Figure 3.2 Thermal image from the drone's camera of a person – circled – at two distances – 25 m (left) and 50 m (right).

Source: Images from Asmussen and Thomsen (2021), used with permission.

population could collect such data during SaR missions and use it later for other unintended purposes.

It may seem that privacy is unimportant in a search and rescue operation, or at least much less important than other values (Van Wynsberghe & Nagenborg, 2016); this is a value conflict between the value of privacy and the value of human welfare (see "Value Conflicts"). Although human welfare is probably the value with the highest priority in a SaR scenario, privacy protections should be supported as much as possible. The privacy-by-design (PbD) guidelines introduced earlier provide some suggestions for responsible drone design (see "Privacy"): full functionality with privacy built in, data minimization, and security of the data that is collected throughout its entire lifecycle.

The prototype SaR drone has some privacy-preserving capabilities but could also collect private data. The video signals from the drone are encrypted using a pixel-scrambling algorithm, making it difficult to intercept the transmission and view the video feed. The thermal camera has a limited capability to capture biometric data (i.e. their face) (see Figure 3.2). In Denmark, all personal data must be secured in compliance with the European Union General Data Protection Regulation ("General Data Protection Regulation," 2016). Search data could be stored in a secure database only accessible to the relevant SaR personnel, and then deleted once the victim is found.

3.1.4 Jobs

The introduction of SaR drones would have an impact on jobs and the work that people perform on a daily basis. Although here the SaR drone is conceived of as an addition to an operation mostly conducted by humans in the field, there is nothing preventing technology from taking over and performing most or even all of the SaR missions. One could even imagine a scenario in the distant future where swarms of drones and robots are set into motion the moment a person is lost, operating fully autonomously with no humans involved. This would mean job loss for human search and rescue personnel, but more jobs for drone and robot developers, operators (if they are still needed), and drone manufacturers. It would mean a shift from the cultivation of practical skills, knowledge, fitness, physical dexterity, and courage (see "Virtue Ethics") in a blue-collar job, to those of technological skills, knowledge, and competence in a data-driven white-collar job. These two support and reward different types of career development, education, competence, and conceptions of a flourishing society.

According to the crew chief of the Danish SaR helicopter, the most effective tools must be used, even if it puts their jobs at risk – the well-being of the people they are rescuing comes first (Asmussen & Thomsen, 2021) . However, it is possible that not all of the crew chief's peers share this selfless approach to their jobs, and engaging more stakeholders would provide a better idea of the general attitude of Danish SaR personnel toward their careers and automation. Again, the Danish workforce is at less risk than those in other countries with less social welfare, but the costs to support the unemployed could quickly get out of hand.

3.1.5 Environmental Sustainability

The SaR drone could both enhance and diminish environmental sustainability. It could enhance sustainability by reducing the amount of time a full-sized helicopter needs to operate during a mission, reducing the use of jet fuel, the production of CO_2, and a multitude of other environmental impacts. Drones could be less disturbing to birds and other animals than a helicopter. However, drones pose their own threats to sustainability, including their use of rare materials such as lithium, neodymium, and gold. The batteries require electricity to charge, and this can be more or less sustainable depending on the energy source of the grid – in Denmark, this is about 60% renewable and 40% non-renewable ("Renewable energy in Denmark," 2022). Still, the overall impact of small drones – unless a massive number of them are used – will be orders of magnitude less than that of a full-sized helicopter.

The prototype SaR drone's frame is made from wood to enhance environmental sustainability (Cawthorne & Iversen, 2021) . In the previous case, the healthcare drone's carbon fiber frame was the most significant contribution to CO_2X (CO_2-equivalent) production, which is why the SaR drone's frame uses alternative materials. The drone's arms are built up of mahogany hardwood veneers on top and bottom, with an end-grain balsawood core in the middle; the resulting sandwich structure is both lightweight and strong. The health (i.e. toxicity during manufacturing) and environmental impacts of the wooden structure are around ten times lower than carbon fiber. Wood is a renewable resource, and locally available wood can be used – for example, Black Walnut or spruce in North America, or European Walnut in Europe and Scandinavia. However, responsible farming practices – such as the cultivation of the tropically grown balsawood tree – and fair wages for growers are required to make wood a truly sustainable material. Another risk is that people might not trust the wooden structure as much as one from a "high-tech" material like carbon fiber; the value of trust is discussed in the next section.

3.1.6 Trust

Trust is fundamental in a SaR context – the lost person must be able to trust the rescuers, the SaR team must be able to trust their equipment, and the public must trust the SaR team to be skilled and to perform their duties with the minimum of intrusion into their lives. Some victims might be hoping to be rescued and will actively seek out and attempt to signal to the SaR personnel. But some – such as runaway kids or people suffering from dementia – may be afraid or even attempt to hide from the searchers. The prototype drone has been built in order to test the hypothesis that the telepresence system will earn the trust of the victim and facilitate meaningful human–human interaction. The sight of a full-sized helicopter might mean salvation to some, but victim's reaction to the prototype telepresence drone should also be investigated.

Additional data is required to know if the public will trust the drone more than the familiar SaR helicopter. In general, data gathered so far indicates that the Danish public does not like drones that have cameras on them – and this drone has a lot of them – but they seem to accept drones that are used for good purpose, such as SaR, and operated by trusted entities, such as the Danish rescue services (Cawthorne & Frederiksen, 2020).

It is possible that the SaR team might not trust the wooden structure of the prototype drone – the *perception* of wood as a material may be that it is lower performance than that of carbon fiber, even if the data show that it is not (Cawthorne & Iversen, 2021). The wooden frame could be painted to conceal its materials, and information on its performance could be shared with its operators. Still, it will likely take some time before wooden drones are considered as high-performance as carbon fiber and epoxy.

3.1.7 Explicability

The drone's telepresence system is specifically designed to enhance explicability (including both intelligibility and accountability – see Explicability). Rather than an opaque, autonomous drone, the telepresence system could facilitate human–human interaction in a situation where human contact is key. The system will allow the victim to quickly understand that the drone is operated by humans, and that the person they see and are speaking with is from the Danish emergency services.

The drone's non-symmetrical shape is designed to enhance explicability, making it more clear where the front of the drone is, and where the sensors are "looking". The red lights mounted to the outer bumper of the drone increase visibility to victims and other SaR personnel (critically, those in the helicopter). However, these lights give the drone a UFO-like appearance, which should be changed in future design iterations.

3.1.8 Dual-use

This drone has obvious dual-use potential, especially its capability to find people – even those that do not want to be found – which could be used to detect an enemy on the battlefield. The telepresence system could allow medical staff to remotely assess and give advice to those wounded on the battlefield, keeping them from harm's way. It could be argued that this is a preservation of human welfare, but also that any technology which reduces the cost of war makes war more likely. Perhaps the telepresence system could be used for psychological warfare, or the enemy could be remotely prompted to surrender. During the 1991 Gulf War, Iraqi soldiers attempted to surrender to a U.S. "Pioneer" RQ-2A surveillance drone ("Pioneer RQ-2A UAV," 2023). The prototype drone's encryption feature would be valuable in a military context, where concealment of data is key. Still, the prototype drone likely exhibits low survivability – a characteristic useful in military contexts but not in civil applications – and would probably be of limited value in a conflict situation; more capable drones that do not carry unnecessary screens and speakers would likely be used first.

3.1.9 Misuse

The drone's capabilities could make it vulnerable to misuse. Similar drones have been used to identify refugees and migrants at the Belarus–Poland border where Polish border patrol have been accused of pushing people back into the forest to freeze (Gettleman & Pronczuk, 2022). The bright red lights make the drone highly visible, and the sound of the propellers is audible from some distance, making it less useful for spying than alternative means.

3.1.10 Calmness

A telepresence drone could be used for advertising in an annoying and intrusive way[1]. Humans tend to look at moving objects and at things with people's faces on them; the drone could be used in public spaces or even door-to-door. Floating billboards – some as large as 6-by-20 meters – are already causing controversy in coastal Miami and Manhattan in the United States ("Floating billboards turn Miami waterfront into Times Square ", 2019). Drone-based advertising would add a third dimension to the barrage of advertising people are already inundated with.

3.2 The Social Phase

3.2.1 Context

The drone is developed to support Danish inland (i.e. not at sea) search and rescue operations. The Danish context was described earlier in the healthcare drone case (see "Context"), but here some additional considerations will be included that are relevant to search and rescue. Denmark is a small country, and almost all of it is built-up or populated in some way – from most locations other people are not far away. Many SaR missions take place on Denmark's long coastline, or at sea. Some common SaR situations in Denmark involve looking for lost children or people with dementia.

Currently, airborne search and rescue missions are performed by the Danish armed forces, led by the Joint Rescue Operations Center (JROC) using helicopters such as the Agusta Westland EH101 "Merlin" ("Agusta Westland AW101," 2022). This helicopter has a maximum takeoff weight of 15,000 kg and seats up to 25 people with a crew from 3 to 7 people including a pilot, co-pilot, crew chief, medics, and others. The helicopter can airlift injured people, has a cruise speed of 278 km/hr, and an operational range of over 1,500 km. It uses three Rolls Royce turbine engines each producing 2,300 hp and costs around €15,000 per hour to operate.

The prototype search and rescue drone has much more limited capabilities than the SaR helicopter but at a much lower cost and impact on those around it. The drone is most useful in the search part of a SaR mission, and multiple drones could be sent out to search quickly at a relatively low cost to cover a wide search area. But the drone cannot airlift multiple people out of harm's way or deliver medical assistance directly to them, thus making a direct comparison of the two technologies difficult.

3.2.2 Use Plan

The high-level use plan for the Danish SaR drone is envisioned as follows:

- The drone acts as a supplement to the current helicopter and ground-based SaR operation.
- The drone pilot is on-site and an integrated part of the search team.
- The drone is powered on; the red, bumper-mounted warning lights turn on automatically.
- The drone is launched in coordination with ground-based and helicopter-based search team to prevent collisions.
- The drone is used to search areas that are less safe or less accessible to the helicopter, such as areas with high population density or fields with tall grass where the helicopter's rotors would blow down the crops and hide a lost person.
- Multiple drones can be sent out at once to cover the search area faster, with one drone pilot operating each drone.
- The rescuer flies the drone manually but has access to a search pattern recommended by the system.
- The rescuer uses the drone's thermal and RGB cameras to look for the victim.
- The system highlights and notifies the rescuer of potential people identified in the thermal and RGB images.
- If a person is located, the pilot lands the drone close to them.
- The telepresence screen is turned on, and the rescuer interacts with the victim remotely.
- The rescuer calms the victim and assesses their physical and mental condition.
- The rescuer provides guidance to improve the victim's condition.
- The drone's GPS location is used to identify the victim's location.
- Additional services, such as ground or air-based resources, can be sent to the victim.
- The drone is retrieved at the site of the victim, or if no one is found, flies back to the launch site.

3.2.3 Stakeholders

Adding the SaR drone into the emergency services system would have an impact on a multitude of different stakeholders. Direct stakeholders include the lost people, the helicopter and ground-based rescuers, wildlife including birds in the area, pilots and passengers flying in aircraft near the operation, the drone pilots, drone developers, and drone manufacturers. Some indirect stakeholders are the people who are overflown by the drone during an operation, police and other emergency services, and the Danish military. As mentioned earlier, victims in SaR scenarios are often highly vulnerable, including lost children or disoriented elderly people; therefore, a high level of responsibility and robust empirical investigations (discussed next) must be used when developing technology for them.

3.2.4 Empirical Investigation

The prototype SaR drone was developed with input from a direct stakeholder: the crew chief of a Danish search and rescue helicopter (Asmussen & Thomsen, 2021). Inputs were gathered through a value-oriented semi-structured interview (Friedman & Hendry, 2019); the interview was audio recorded and a transcript made. A value-oriented coding manual was developed, and the following values were identified as relevant:

- Safety – that of the rescue crew and those exposed to the operation
- Ownership and property – the downwash from the helicopter can cause property damage
- Privacy – the crew uses encrypted radios and aims to protect privacy, but the effectiveness of the search operation and the physical welfare of the victim is the top priority
- Material welfare – the helicopter and crew cost around 100,000–120,000 DKK (€13,000–16,000) per hour, so even using many drones could be less costly
- Jobs – the most effective tool should be used to save people, even if drone use means fewer SaR jobs

Empirical evidence mentioned in the previous chapter indicates that the Danish public is open to drones being used to perform important functions, and most would agree that potentially life-saving SaR operations fall into this category (Cawthorne & Frederiksen, 2020). However, there are limits to the amount of disruption citizens are willing to tolerate – according to the crew chief, residents complain about the helicopter, especially if they fly over the same house twice or cause damage (e.g. blowing down a greenhouse) (Asmussen & Thomsen, 2021) .

The crew chief had inputs to the technological specifications of the drone as well. These included:

- Long flight time to extend the usefulness of the drone
- Bright lights and high visibility to make the drone easy to see by others and the helicopter crew – from above and from below
- Automatic identification system (AIS), which transmits the drone's position and altitude to avoid collisions ("Automatic identification system," 2023)

- Direct downward-facing sensors (i.e. camera, thermal camera) to find people in tall grass or in crops
- Privacy-preserving features such as blocking out private property should not compromise the effectiveness of the search operation.

The crew chief relayed a case where the SaR drone could have been particularly useful: a few years prior, a person fell off a cliff onto a ledge, which was inaccessible to rescuers. The helicopter was called, but it took an hour to arrive. In the meantime, a ladder was secured at the top of the cliff, and a rescuer climbed down it to get nearer to the victim. The rescuer was able to assess the victim's condition and to provide psychological aid. The SaR drone could have provided a means of visual and audio communication between rescuers and victim – without putting the rescuer's safety at risk.

In the future, more of the stakeholders listed in the previous section should be engaged with – in particular (in a responsible way) those that have experienced being lost and rescued before.

3.3 The Technological Phase

3.3.1 Description of Materiality

In this section, the inputs from the previous sections – the ethical phase and the social phase – are used to define the materiality of the prototype SaR drone.[2]

3.3.1.1 Size and Configuration

The prototype drone is 1 meter wide, 0.7 meters long, 0.3 meters tall, and weighs 3.3 kg. The drone is a non-symmetrical "Y6" hexacopter (six motor) configuration – the motors are in a "Y", or in this case a "T" shape as viewed from above, with a pair of co-axial motors mounted at each end of the "T".

3.3.1.2 Materials

The drone's frame is made of wood. The arms are a sandwich of mahogany hardwood with a core of end-grain balsawood; the legs are mahogany reinforced with plywood. The electronics and sensors are housed in balsawood boxes at the front of the drone. The "bumper" surrounding the propellers is laminated strips of walnut hardwood held in place with plywood strips.

3.3.1.3 Exterior

A red light emitting diode (LED) light strip is mounted to the outer edge of the wooden bumper.

3.3.1.4 Power System

Six brushless 850 kV, 250-watt (Hacker A30-42S-UAV) electric motors with 11×5-inch wooden propellers and a 12-volt, 35C, 6.2 amp/hour lithium polymer battery pack power the drone.

3.3.1.5 Sensors

A Raspberry Pi HQ video camera and a FLIR Lepton 2.5 micro thermal/RGB (red/green/blue) camera are mounted at the front of the drone and run by a Raspberry Pi 4 model B, 4 GB microcomputer. A Hitec HS55 servo motor actuates the sensor assembly, allowing the cameras and screen to tilt, facing forward or downward. A convolutional neural network (CNN) running a single-shot detector (SSD) algorithm attempts to detect people in the video images in real time (Hui, 2018).

3.3.1.6 Telepresence

There is a seven-inch touchscreen tablet, a microphone, and two speakers at the front of the drone. The prototype used a Wi-Fi hotspot to send encrypted digital video/audio signals – using a pixel-scrambling algorithm – to the ground station and to transmit video of the drone pilot to the tablet. The webcam and mic on the ground station laptop are used as the rescuer's telepresence system, sending video and audio of the rescuer from the ground station to the tablet and speakers on the drone.

3.3.1.7 Control and Autonomy

The flight controller is a Pixhawk PX4 Mini Holybro with a Pixhawk Power Brick mini and Pixhawk GPS. A V2, 433 MHz mRo Robotics radio sends telemetry information to the ground station. A Spektrum DX9 nine-channel DSMx remote control transmitter is used to manually fly the drone.

3.3.1.8 Support Systems

A laptop computer is used as the ground control station, and as the rescuer's end of the telepresence system.

3.3.1.9 Summary of Specifications

- Width – 1 m
- Length – 0.7 m
- Height – 0.3 m
- Weight – 3.3 kg
- Power – 1,500 watts
- Sensors – thermal, RGB video
- Interaction – seven-inch telepresence touchscreen, microphone, speakers

3.3.1.10 Performance

The prototype exhibits the following performance (estimated):

- Flight time – 5 min
- Cruise speed – 15 km/h
- Maximum speed – 25 km/h
- Range – 1.1 km

3.4 Should This Drone Be Built?

Maybe, but only after significantly more stakeholder engagement, refinement, and testing.

This drone prototype was built as an experiment to assess a number of design features, and as such it still needs a fair amount of refinement in order to become a useful product. Fundamentally, the capabilities of the drone are much different than those of the technology currently being used, making a direct comparison of the two impossible. A SaR helicopter is an extremely powerful piece of equipment, with the associated expense, complexity, and personnel required to operate it. And the values its use and mastery cultivated are different than those of drone-based operations.

The key feature of the drone – its telepresence system – needs to be tested in realistic SaR scenarios. If it supports human–human interaction and cultivates trust, then it could be a promising alternative to autonomous drones with lower levels of intelligibility and accountability. Perhaps most of the benefits of the telepresence system could be attained through microphones and audio, which would reduce the weight, cost, and complexity of the system. At a minimum, the size of the telepresence video screen could likely be reduced and still support human–human interaction.

The drone's flight time was not optimized in the prototype, and as it is, the drone's usefulness is quite low. The telepresence screen is large and heavy, and counterweights were required to balance the drone, further increasing its weight. Multirotor drones of this size that have been refined can be reasonably expected to have a flight time of around 30 minutes. Still, it might be preferable to investigate the use of a VTOL drone (see Figure 1.2), which will have a longer flight time than a multirotor drone, but still be able to take off and land vertically near the victim where they can then interact with the telepresence system.

The prototype drone's explicability could be enhanced in a number of ways. The red bumper lights should be changed, and the rounded shape replaced with one that has straight lines and sharp corners to avoid looking like a flying saucer. The lights could be moved to the frame of the drone, and the front where the sensors and screen are located could be highlighted. Lights should be mounted on both the top and bottom of the drone, so it is visible from below by the victim, and from above by the helicopter crew. Flashing lights should be added, which would increase the visibility of the drone, and the frame painted in high-visibility green to resemble the SaR helicopter increasing accountability. Like the healthcare drone (see "Explicability"), all of the sensors such as the cameras should be clearly labeled, increasing intelligibility. There is another value conflict here – a less visible drone could be more useful in finding people that do not want to be found: runaway kids or scared people with dementia, for example. But this would increase the drone's capacity for dual-use and misuse.

Many Danish SaR missions are located at the coastline or at sea, so a drone that is well-suited to a marine environment would be more useful. For example, it could have affordances to land on water if needed, along with a search strategy based on the predicted movement of ocean currents, and sensors attuned to finding people in the water.

The capabilities of the AI used for detecting lost people brings up an important value conflict (Harbers et al., 2017): the AI might be able to assist in detecting a person in an image automatically, but it could miss the person (false-negative) or suggest something that is not a person (false-positive). The latter has less serious consequences – distracting the rescuer briefly, but the former might prove deadly. Who is to blame should the system fail? Who should be praised when the system works well? The system could reduce search time and increase effectiveness and therefore saving lives; in this case, it could be argued that one has a moral *imperative* to develop and use the technology as this is a preferable outcome to doing nothing.

If used, the AI should be trained on data that addresses issues of bias. For example, if the system is trained only on adults, a bias will be created, which could mean it is less capable of identifying lost children. Therefore, training data should contain images of people representing a range of ages, heights, body types, gender, ethnicity, and clothing, among others.

Another AI-related risk is that the rescuers become overly reliant on the system's suggestions and de-skilled in this key part of their jobs. AI is already being used in the medical field for radiology predictions, detecting diabetes, and breast cancer screening; soon, doctors could lose the skills required in manual detection. From a Marxist perspective, robots, drones, automation, and AI are ways to reduce investment in human capital (i.e. human skills), and to weaken the bargaining power of the working class (Duran, 2021).

Notes

1 This potential harm was identified by my students in an exercise called "the evil drone awards". An exercise in opposites, the "most evil" idea wins a small metal statuette of a drone with devil horns on it.

2 This chapter is based on research performed together with two of my drone masters students (Asmussen & Thomsen, 2021).

4 The Sierra Leone Educational Drone

4.1 The Ethical Phase

4.1.1 Human Welfare

The prototype educational drone was built to investigate using low-cost and locally available materials for teaching about drone technology in West Africa (Figure 4.1). It might help engineering students understand drone technology and eventually create companies after graduation, enhancing material welfare. But the drone's direct impact on human welfare would likely be modest. More critically, Sierra Leone has just passed land reform laws, and drones will probably play a key role in mapping 99% of the country, which still relies on customary land rights. The physical, psychological, and material welfare of many citizens of Sierra Leone is directly linked with their property rights – land provides work and income, as well as food. In the future, developing a mapping drone based on the educational drone could help secure property rights for the most vulnerable in society. There could be benefits to material welfare and jobs through locally manufactured drones in Sierra Leone. Currently, there is limited design and manufacturing in the country – most goods are imported, while raw materials are exported – so this move could foster internal capacity building. Manufacturing drones at home could increase ownership of the technology, giving it a lasting impact. At a minimum, drone engineers from Sierra Leone would understand the technology and be able to advocate for good drone use, and push back against exploitative practices from outside interests.

Technological imperialism is when technologies from abroad that support the values of outside powers are pushed onto the less powerful (Nussbaum, 2010). An example of this is the One Laptop Per Child (OLPC) project, a likely well-intentioned but disastrous attempt at increasing human welfare in Africa through education (Ames, 2019). The project aimed to provide every child in Africa with a laptop and was funded mostly by outside

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Figure 4.1 The prototype educational drone built in Denmark (top). Alfred Mbayoh launches a bamboo drone – this one made by engineering students at Fourah Bay College in Freetown, Sierra Leone in September 2022 – for its first test flight (bottom).

Source: Top image by the author and bottom image from video by Kenneth Bamba, used with permission and with permission of those in the p hoto.[a]

a Thanks to the Year 2 Electrical and Electronics Engineering students (2021/2022 academic year), Year 2 Mining Engineering students (2021/2022 academic year), Ing. Kenneth Abdul Bamba (Research Teaching Assistant at Fourah Bay College), Alfred Mbayoh (CEO and founder of LEOTECH), and Dr. Solomon Tucker (Head of Mining Engineering Department) at Fourah Bay College for permission to use this image, for hosting the "Good Drones in Sierra Leone" seminar, and for building and testing their own bamboo drone.

interests: western tech companies such as ADM, eBay, and Google. The idea was that if kids could learn to write code, a multitude of opportunities would open up for them. The specially designed laptop's initial design included a hand crank for power, but this was quickly abandoned as it was a failure point in the design. Unfortunately, reliable electricity was not available in many places the laptop should be used. More than 3 million laptops were distributed, but the project was deemed a failure by many. Critics said that it utilized an overly "U.S. mindset" and was not useful for "African problems" or appropriate for the context of use ("One Laptop per Child," 2023). The money from the project could have been used more effectively in other ways, such as on basic healthcare for the children.

Similar to the OLPC project, it could be argued that there are more important things than drones that engineering students in Sierra Leone should be learning about. There are few drones in the country and almost no infrastructure to support their construction or operation, so students' time might be better spent on urgent engineering tasks that directly impact people's welfare such as building infrastructure to supply clean water, improving roads, and creating a more reliable energy grid to take just a few examples.

4.1.2 Safety

The prototype educational drone is relatively safe – at cruise speed, it has a kinetic energy of 34 Joules, which has been categorized as "harmless" (la Cour-Harbo, 2017). However, the motor and propeller are at the front of the drone, which forms a point and is likely the first part of the drone to impact someone or something. Impact on a person's eye could cause it to rupture. The motor is not powerful enough to cause serious harm, but it could cause cuts.

Sierra Leone is a more dangerous place than many western countries. Sometimes, financial or practical constraints lead to compromises making the general approach to safety much less strict. Western companies could be accused of taking advantage of the less restrictive safety legislation in Africa in order to test their products before transferring them back to the West. Arguably, this has been the approach of the world's largest commercial drone operator Zipline,[1] which gained permission to operate from Rwanda's president Paul Kagame. The Silicon Valley company has developed their blood delivery drones in Rwanda since 2016 and is now expanding to deliveries in South Carolina in the United States ("Zipline – drone delivery company," 2023). By now, the drones are very robust – but the safety risks during their development were placed upon Rwandan citizens without their consent. The local economic benefits appear limited, and – although the drone is very fast – the cost of blood delivery in Africa by drone has been found to be very high compared with traditional motorcycle delivery (Phillips et al., 2016). As mentioned earlier, some have suggested that resources invested in drones should better be used to build roads – a more democratic technology that benefits more of the population.

It could be argued that engineers everywhere should cultivate the virtues of justice and care – to treat people fairly and ensure their well-being, a virtue ethics approach (see "Virtue Ethics"), and that only technologies which are considered safe by western standards should be introduced in Africa. It could as well be argued that western safety norms are not relevant in the local context – a deontological argument (see "Deontology"), or that placing such restrictions on safety could compromise the *overall* good a technology could do – a consequentialist argument (see "Consequentialism"). Therefore, the normative approach to technological development – discussed later in "The Ethical Phase Methods" – is important.

4.1.3 Privacy

Drones could add a new risk in Sierra Leone – critically, risks to privacy. Although the educational drone does not carry a camera, one could be retrofitted to it fairly easily. A mapping version of the drone would certainly have a camera. Such a drone could collect data that people do not want to be shared, such as their material living conditions, crops, assets, and even personal/biometric data. It seems likely that this would result in a significant risk to the privacy and dignity of many, especially poor and vulnerable people. However, when the mapping of Sierra Leone takes place – probably, using a combination of satellite imagery for orientation, crewed aircraft with high-resolution cameras, walking land boundaries using RTK GPS (a more precise version of GPS), and drones – the trust of citizens and landowners must be respected, and only data required to define the land boundaries captured.

4.1.4 Jobs

The prototype drone can be built by engineering students – or eventually by local craftspeople – using inexpensive and readily available materials. This could create jobs and support the development of high-tech domestic manufacturing. Technology may be a key feature in economic growth and consequently a way to improve material welfare and living conditions. Importing technologies from abroad causes dependencies on outside interests and supply chains which may reduce ownership, and which risks technological imperialism; designing and locally manufacturing technologies suited to the context and needs of the people would be an antidote. Drones could be a potentially empowering and economically stimulating technology in Sierra Leone, especially drones developed and used for mapping tasks to establish land rights. Mapping Sierra Leone will require a large workforce of surveyors, civil organizations to manage boundary harmonization, and – potentially – drone operators. Still, the direct usefulness of drone jobs compared with those that address other more urgent tasks could be called into question.

4.1.5 Justice

The world is an unfair place, and this is evident in Sierra Leone – there is limited access to basic infrastructure, education, healthcare, and economic stability. The few students that are lucky enough to study engineering do not have access to the newest and best educational resources. With regards to mapping, land is often leased cheaply to foreign interests such as mining companies and for agricultural production including the prolific cultivation of palm for palm oil. The prototype education drone could play a small part in reducing some of these injustices. Having a low-cost drone made from locally available materials would make it more accessible to Sierra Leone's engineering students, and the drone could be an early step in capacity building of technological educations.

Justice is a key aspect of critical geography, a theoretically grounded approach to geography, which promotes social justice and seeks to upend structures of domination ("Critical Geography," 2021). "Maps are not just tools for navigation but also instruments of power and appropriation, subversion and resistance, leverage and negotiation" (Venturini & Munk, 2021). In Sierra Leone, one of these power struggles is playing out between western companies that want access to the country's natural resources and the landowners. Maps could be used to support taxation by the government, and, if the maps contain data not just about land area but also the land's contents, used to estimate demographics, populations (i.e. counting the number of buildings in a village) and resources (such as plantation sizes and crops) with important consequences. This could influence where to build a new school, which jungle to cut down for agriculture, etc.

During a mapping exercise in Kalangba, Sierra Leone, the local farmers were amazed at the capabilities of the commercially available drones brought by the author and Engineers Without Borders Denmark (discussed more in The Social Phase). One of the villagers remarked that the drone was "white-man power"; this anecdotal evidence suggests that technology is viewed as something that comes from outside of Sierra Leone and is developed by and serves the interests of outsiders. The prototype educational drone could be a way to address this power imbalance. Alternatively, this pressure of technologization could be rejected – it is possible to act in a just way and to live a meaningful life without embracing technology. This leads to some meta-ethical questions: What constitutes a meaningful and just life? What is our responsibility as a human race to make the world more just?

4.1.6 Environmental Sustainability

The environmental impact of the Sierra Leone drone is low compared with commercial off-the-shelf drones. An earlier study showed that a drone's main environmental impact can come from its carbon fiber frame (Cawthorne & Iversen, 2021). The educational drone's frame is made from bamboo, which can be locally sourced and is a very low-impact material with a high strength-to-weight ratio. The frame is covered with clear plastic film that can be sourced from plastic waste, and the tail is covered in fabric, which can come from old clothing. The flaps are made from cardboard, which is also easy to come by in the form of discarded cardboard boxes; bee's wax can be used to protect the cardboard from moisture.

The second most impactful part of the drone in the previous study was the electronics. The educational drone uses standard drone electronics, and therefore creates a similar environmental impact to that of the drone in the study. However, the use of discarded electronic components could potentially address this issue. Electronic waste, or e-waste, is a global concern with around 50 million metric tons being generated each year (Baldé, Wang, Kuehr, & Huisman, 2014). An autonomous version of the drone is being developed by the author and several students; it is built using an Android smartphone for the flight controller and the built-in sensors (i.e. camera, GPS, accelerometers, etc.). Although more expensive than drone-specific parts, smartphones have high-performance processors, sensors, and cameras. Critically, these phones can be sourced second-hand in Sierra Leone, which would eliminate supply chain dependencies compared with importing a drone flight controller. Further work is needed to fully realize the use of locally available, low-cost, and e-waste electrical components, but the following are works in progress:

- Airframe – easy-to-manufacture design with locally sourced materials including bamboo, hardwood, cardboard, plastic film, steel wire, fabric, foam, etc.
- Propeller – hand-carved from locally sourced hardwood
- Motor – direct-drive DC motor from cordless drill
- Electronic speed controller (ESC) – modified electronic speed controller from cordless drill, or ESC built-up from power supply transistors
- Battery – modified lithium-ion cordless drill battery

- Flight controller and camera – second-hand Android smartphone with flight controller app
- Actuators – stepper motors from e-waste printers

There are value conflicts between the benefits of using low-cost, readily available, and more easily repairability “sustainable drones” like these, and using optimized commercial drone components, which, in most cases, would result in a higher-performance drone as judged on typical parameters such as flight time and payload.

4.1.7 Trust

Drone use is still very new in Sierra Leone, and their public perception as trustworthy or untrustworthy is for the most part yet to be formed. There have not been major military or terror operations using drones in Sierra Leone, which would cultivate active mistrust of the technology. The prototype drone’s bamboo, cardboard, and plastic film construction will likely be perceived as less trustworthy than a commercially available drone such as the eBee or Mavic used in the mapping exercise. A hypothesis was that the prototype drone’s locally sourced materials (i.e. bamboo, the familiar textile on the vertical tail) would engender trust due to its local sourcing and familiarity. However, anecdotal evidence from the empirical work (see “Empirical Investigation”) indicates that products from Africa are perceived to be of lower quality than products from abroad (i.e. China, United States, Europe). This will create challenges for any local industry, including a local drone industry. However, it could be a positive change to overturn this perception and to support high-tech design and manufacturing in Sierra Leone through drone technology.

In educational contexts, trust issues are less critical since the drone’s only purpose is for teaching, but in land mapping trust is critical. In mapping, lower levels of trust would be well-founded as the drone’s reliability is much lower than highly developed commercial products, but the quality of data it could collect would be as good (or perhaps better due to increased satellite coverage gained at higher altitude) as other technologies using GPS. A more refined looking drone – although it might be less environmentally sustainable and low cost – could help bolster the perceived quality of the drone and generate more trust. Again, there is a value conflict here which must be addressed.

4.1.8 Explicability

The drone’s plastic covering is see-through, and its components are visible increasing intelligibility. It is easy to see if the drone is carrying something nefarious inside (see "Misuse"), and – for people familiar with drones – how it works. Intelligibility could be increased further by adding symbols and markings, as was done on the Danish healthcare drone (see "Explicability"). For example, "education drone" or the name of the university could be written on the underside to be visible from below, and a camera symbol could be added if the smartphone camera is used. Both versions of the drone should announce their presence to those nearby to not be interpreted as spy drones, so adding bright flashing lights could be a beneficial upgrade. The drone's unique triangle shape would differentiate it from other flying objects, and it should be clear which way it is flying since it is always moving forward, propeller-first.

There are not many drones operating in Sierra Leone, which will have an impact on accountability. The remote-controlled educational drone will exhibit a higher degree of human accountability – the pilot will have to be within visual line of sight of the drone – than an autonomous mapping version, which could fly far from its operator.

4.1.9 Dual-use

There have been armed conflicts in Sierra Leone in the past, including the civil war ending in 2002 and it is conceivable that low-cost bamboo drones could be used in domestic and international military or civil war operations. Although their performance is low compared to commercial drones, their low cost lends itself to being disposable – they could be filled with small amounts of explosive and turned into kamikaze drones. Commercial kamikaze drones are being used by both Russia and Ukraine in the current conflict, and although not resulting in massive casualties the drones are striking fear into the enemy and civilian populations making them an effective psychological weapon ("How are 'kamikaze' drones being used by Russia and Ukraine?," 2023). Even without modification, the mapping drone could be used for military reconnaissance, autonomously gathering images of the enemy's numbers, locations, and assets from the air. Its low speed (and added flashing lights) would make it an easy target with low survivability (Van Wynsberghe & Nagenborg, 2016), and any drones that were shot down or intercepted would show the location of launch giving away their operator's location, but the low investment could offset these limitations.

4.1.10 Misuse

Many of the features of the prototype drone that make it low-cost and easy to manufacture also make it easier to misuse. This is a general problem with accessibility – the more people that have the chance to use a technology, the greater the chances that someone uses it in a way that was not intended. Do-it-yourself technologies' lack of traceability is a benefit in misuse.

The controversy surrounding 3D printed guns highlights the risks that ease of accessibility and lack of traceability pose. The first widely distributed 3D printed gun, The Liberator, was created in 2013. The digital design files of the gun were downloaded 100,000 times within two days of being uploaded to the open-source repository DEFCAD before being shut down by the U.S. government ("The Liberator–the world's first 3D printed handgun," 2023). Referred to by law enforcement as "ghost guns", these weapons have no serial number or traceability (Hamilton, 2021). The U.S. government was also concerned about possible International Traffic in Arms Regulations (ITAR) violations – "transferring technical data to a foreign person, whether in the United States or abroad". The extreme libertarian values of the gun's creator were well embodied in the technology but resulted in conflicts with legal entities and gun control advocates just to name a few. This example may serve as a cautionary tale about the limits of ease of access to information and open-source ideals: some knowledge may be dangerous in the wrong hands and perhaps access should be intelligently managed. In the case of the bamboo drone, access could be limited to trusted partners and educational institutions. Still, institutions change leadership and companies change owners and employees, so this is not a perfect strategy. And the drone is fairly simple – it would not be difficult to reverse-engineer.

4.2 The Social Phase

4.2.1 Context

This drone is developed for educational purposes in Sierra Leone. Sierra Leone is a country in West Africa on the coast of the Atlantic Ocean. It contains mountainous regions – such as the capitol city of Freetown shown in Figure 4.2, flat low-lands, jungles, and mangroves. The country covers almost 72,000 square kilometers in area and has a population of 8.4 million people ("Sierra Leone,"). Most of the population (97%) speaks Krio, and English is the official language used in school and in official administration ("Sierra Leone," 2023a).

Freetown was formally established in 1792 by the British as a colony for freed slaves (Shaw, 2020). Since gaining its independence in the 1960s, Sierra Leone has suffered from a series of social, economic, and political hardships. What some have called a civil war that took place from 1991 to 2002, those familiar with the region have called a struggle for control by diamond cartels. Ebola struck Sierra Leone from 2014 to 2016, with the sick and those suspected of being sick taken to fortified Ebola camps

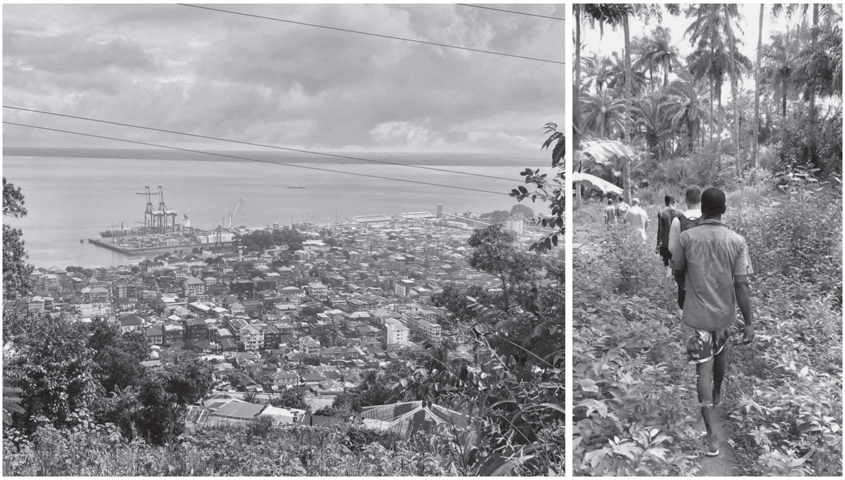

Figure 4.2 Sierra Leone: the capitol – Freetown (left) and a plantation in the Kalangba village of Port Loko district (right).

Source: Images by the author.

(essentially prison camps) to die. Additional risks in Sierra Leone include traffic accidents, which kill 41 people per 100,000 (for comparison, there are 3 deaths per 100,000 people in Denmark per year ("Estimated road traffic death rate (per 100 000 population)," 2019)). The average life expectancy at birth is 59 years for men and 61 years for women; the global average is 73 ("Life expectancy at birth (years)," 2020).

Around one-fourth of school-age children in Sierra Leone do not attend primary education, and only 64% of those that do complete the education ("Education in Sierra Leone," 2022). Thirty percent of the adult population (over 15 years old) is unable to read or write ("Sierra Leone–Education and Literacy," 2023). Seven percent of the population has a university education ("Sierra Leone–Education and Literacy," 2023). Twenty-six percent of the population has access to electricity, and 18% to the internet ("Sierra Leone," 2023b).

Although the land is rich in natural resources including diamonds, gold, and aluminum, and there is a good climate for agriculture with two growing seasons per year, the average income per capita is €500 and 26% of the citizens live on under €2 per day ("Sierra Leone," 2023b). Many of the poor are farmers that live outside the capitol, and over 60% of the population of Sierra Leone depends on farming for their livelihood and for food. However, land rights in Sierra Leone are not well documented.

Only the capitol of Freetown has an officially documented cadastral (i.e. land boundary) system, while the other 99% of the land area relies on customary land rights. In 2022, these customary land rights have been made into law ("The Sierra Leone Customary Land Rights Act," 2022), which includes increased protections against industry in protected areas, and guarantees women equal land rights. The World Bank is supporting the country in this undertaking, providing $41 million for the Sierra Leone Land Administration Project (Thomas, 2022). Documenting the boundaries of all the property rights in the country is a daunting undertaking, and will include the crucial boundary harmonization task where neighboring landowners and chiefdoms must agree on where the border between their property and their neighbors lay.

4.2.2 Use Plan

The use plan for the remote control, educational version of the drone – focused on pedagogy – is:

- The drone is built by engineering students from low-cost, locally sourced materials for the airframe and commercially available remote-control airplane and drone electronics.
- The drone is hand-launched by an assistant.
- The drone is flown manually using remote control by a pilot on the ground.
- The drone is flown from an open area such as the nearest soccer field.
- The pilot practices flying and explores the drone's flight envelope (i.e. stability, control, stall speed, max speed, maneuverability).
- The power is cut off, and the drone is landed on its belly.

The use plan of the in-development, autonomous version of the drone for mapping is envisioned as such:

- The drone is built by local craftspeople.
- The drone acts as a supplement to other mapping equipment.
- The drone is used to map small, concentrated areas of interest such as the buildings in a rural village.
- The drone is pre-programmed on the ground using the smartphone app.
- The drone is flown from an open area such as the local soccer field.
- The drone is hand-launched by an assistant.
- The drone flies autonomously over the area to be mapped.
- The drone cuts the power off, and lands on its belly.
- The images captured by the drone are analyzed on the smartphone and downloaded to a laptop.
- The images are stitched together using open-source software to create one large map.

- The map is printed out and given to the villagers.
- The map data is deleted, and only land boundary information is saved.
- The boundary data is used to create official maps and define land boundaries by the Sierra Leone Ministry of Lands, Housing, and Country Planning.
- Physical markers are installed at the borders to document the land boundaries.

The use plan for the educational drone was demonstrated in September 2022 at Fourah Bay College in Freetown, Sierra Leone, by the author and engineering students there (see Figure 4.1). Using the drone as a practical mapping tool is less likely due to its limited performance and reliability. Still, developing the drone with a useful purpose in mind could lead to important capacity building and eventually to the development of higher performance – but still locally built and repairable – drones in Sierra Leone.

4.2.3 Stakeholders

The drone could eventually impact a number of stakeholders. The educational drone would be most relevant to engineering students and local universities such as Fourah Bay College ("Fourah Bay College," 2017). The mapping drone could impact local and international surveyors, nonprofit organizations such as Engineers Without Borders, civil society organizations such as Green Scenery Sierra Leone ("Green Scenery Sierra Leone," 2022), the World Bank, the Sierra Leone Ministry of Lands, and citizens living in the 99% of the country that is not officially mapped.

4.2.4 Empirical Investigation

The author traveled to Sierra Leone as a volunteer with Engineers Without Borders Denmark ("Engineers Without Borders Denmark," 2023) for 10 days in September 2022 (Figure 4.3). The aim of the visit was to investigate drone education and use for mapping in the country. The trip involved meeting with stakeholders in person after a year's remote collaboration and to better understand the local context through rapid ethnography, which is:

> field work done in natural settings, the study of the large picture to provide a more complete context of activity, an objective perspective with rich descriptions of people, environments and interactions, and a bias toward understanding activities from the informants' perspective.
>
> (Millen, 2000)

Figure 4.3 The author moments before launching the senseFly eBee fixed-wing mapping drone into a swamp on the edge of a plantation in Kalangba, Sierra Leone.

Source: Still image from video by Jonas Berg, used with permission.

The pedagogical objectives of the trip were to introduce engineering students at Fourah Bay College to drone technology and to ethics, and included a public seminar titled "Good drones in Sierra Leone" attended by about 60 students. This exercise culminated in the students building and test-flying a bamboo drone with an airframe made from materials sourced at the local market. The cost of materials was $17, and the students were able to build the drone in a few hours' time.

The trip also included mapping of two plots of family land in Kalangba village using two commercial-available drones. Figure 6.2 shows the author attempting to launch one of the drones, the SenseFly eBEE ("eBee," 2023) – one launch went well, and another ended up with the drone in a swamp. Luckily, a DJI Mavic 2 Pro (DJI, 2023a) quadcopter was available as a backup so mapping could proceed. The locals were provided with the resulting maps, and the mapping data and experience in using drones for mapping in Sierra Leone was reported to the Technical Working Group (TWG) at the Sierra Leone Ministry of Lands and to the World Bank.

The pervious drone prototypes in this book were developed in Denmark where the author has lived for over a decade and is familiar with the context.

This project required extensive research, a year's worth of planning and collaboration with local partners, and an in-person visit to better understand the relevant technological, social, and ethical considerations.

The empirical investigation was performed using rapid ethnography (Millen, 2000) with the teaching activities and mapping operations used as learning tools. The following data were collected:

- Society is fairly hierarchical, with the older, rich, white/foreign, city-dwelling, land-owning, educated, and male at the top.
- There is not a lot of infrastructure, and that which is in place can be unreliable – for example, the roads that exist are often damaged, and the electricity in Freetown cuts out a few times per day making backup generators necessary (for those that can afford them).
- Some good roads have been built by f.x. Chinese companies, but these require paying tolls.
- The government is not always trusted by the citizens (especially the police); civil society organizations are more trusted by the people.
- According to many there, education will play a key role in the future development of the country; one challenge is that the few that get a higher education may leave Sierra Leone for better jobs or living conditions abroad, and take their knowledge with them.
- Drones are new technology in Sierra Leone, with perhaps only a few currently being operated in the country.
- The environmental conditions in Sierra Leone are challenging for drone operations – sometimes there are high temperatures or extreme rainfall (especially June–September); there can be dense vegetation and lack of open spaces for drones to take off and land.
- People are worried about their land and resources being taken away by outside interests; during our trip, most people were enthusiastic in welcoming us, but some were critical and questioned our motives.
- In Kalangba, the villagers found the drone's performance amazing and were impressed by how high it could fly; one villager called the drone "white-man power".
- There is not a lot of domestic manufacturing, and products made in Africa are perceived as being lower quality than those from abroad (i.e. China, the United States, and Europe).
- There is some craft industry, including wood carving and sewing of clothing.
- There is a tradition of building kites from sticks split from the stalks of palm fronds and covered in plastic; the kites are flown on the coastline and from hills, such as at Mount Aureol in Freetown.

4.3 The Technological Phase

4.3.1 Description of Materiality

In this section, the physical properties of the prototype Sierra Leone educational drone are presented (see Figure 4.1).

4.3.1.1 Size and Configuration

The prototype drone is a delta-wing configuration aircraft – so called because it resembles the Greek letter delta (Δ) from above. It has a 130 cm wingspan, is 115 cm long, 40 cm tall, and weighs 980 grams.

4.3.1.2 Materials

The drone's airframe is constructed from thin bamboo sticks (around 7 mm in diameter) that are held together with rubber bands, electrical tape, and hot glue. The airframe is covered with clear plastic cling film (normally used for food storage), and the vertical tail is covered in fabric. The motor mount is made from lightweight plywood; the control horns on the flaps are made from solid bamboo, and the pushrods from steel wire. The flaps are built up from cardboard, which could be protected from light moisture with clear packing tape. The flap hinges are made from tape, and the access panel in the top of the drone is reinforced and closed with clear packing tape as well. Packing foam is used to hold the electronics in position inside the drone.

4.3.1.3 Exterior

The exterior appearance of the drone is characterized by its distinctive shape, the clear plastic covering, and the colorful fabric tail; otherwise, it has no external embellishments.

4.3.1.4 Power System

The prototype uses high-performance drone components for the power system; these include a 140-watt brushless motor (Hacker A20-26M) and 12-amp brushless electronic speed control (Hacker X-12 pro). The motor is coupled to an APC 8X4-inch electric slow-flyer propeller via a "prop saver" mount: rubber O-rings hold the propeller to the hub but allow the propeller to pop out of place to prevent being broken upon landing. A three-cell, 11.1 volt lithium polymer drone battery with 850 mAh capacity provides energy for the motor as well as for the servos and receiver.

4.3.1.5 Sensors

The prototype educational drone does not include any sensors. However, the in-development mapping version will use a Samsung Galaxy S3 smartphone (or similar) running Android 4.2 (released in 2012) with its built-in camera, GPS, and three-axis accelerometer. The smartphone's camera will face downward to take aerial images of the ground; the camera has a resolution of 8 mega-pixels (3264 × 2448) giving a ground sampling distance (i.e. resolution of the map) of 2.5 cm when flying at an altitude of 65 m.

4.3.1.6 Control and Autonomy

The aircraft has a positive aerodynamic stability when balanced correctly. The prototype drone is remote controlled – the pilot on the ground flies it directly. Control is executed through a four-channel DSMX hobby receiver (Spektrum AR400), which controls the two flaps at the trailing edge of the wing using two 8-gram hobby servos (Hitec HS-55). The flaps are in an "elevon" configuration, which gives control in the pitch and roll axes; thrust control is provided by the motor and electronic speed control.

4.3.1.7 Support Systems

In its current configuration, the aircraft requires a remote control and pilot on the ground within visual range of the drone. In the future, an autonomous, mapping version of the drone would not require any support systems – the flight path planning as well as review of the collected mapping data/images would be accessed through the Android smartphone itself.

4.3.1.8 Summary of Specifications

- Wingspan – 130 cm
- Length – 115 cm
- Height – 40 cm
- Weight – 980 g
- Power – 140 watts
- Sensors, remote control configuration – none
- Sensors, autonomous control configuration – Android smartphone built-in camera, GPS, and accelerometer

4.3.1.9 Performance

The following performance estimates of the educational drone, based on initial flight testing:

- Flight time – 7 min
- Cruise speed – 30 km/h
- Maximum speed – 40 km/h
- Range – Must remain within visual line of sight

4.4 Should This Drone Be Built?

The educational drone – maybe.

The mapping drone – no.

"When you have a hammer, every problem looks like a nail", and when you have a drone, every problem might at first appear to be one a drone can "solve". Unfortunately, it seems there are much more important things for engineers to do in Sierra Leone that will make a real difference in peoples' lives before drones come into the picture. The work Engineers Without Borders Denmark has been doing in the past – primarily focused on providing clean water – are making a widespread positive impact. A reliable energy grid needs to be established, roads built, existing roads improved, healthcare and child development services bolstered, and education spread and advanced.

Education may be a key aspect for the future development of Sierra Leone and was mentioned by many stakeholders during the empirical investigation. The educational drone could play a small role in introducing some high-tech concepts and support hands-on learning in Sierra Leone.

Perhaps an incremental approach to the technology would be appropriate; for example, first students could build traditional kites to learn the fundamentals of aerodynamics and mechanical strength calculations. Then, a smartphone/camera could be added to the kite to introduce flying sensors and aerial data collection. Students could then build a remote controlled and finally an autonomous drone. This training would allow students to make drones to solve problems that they and their fellow citizens face, and drones that are customized to this particular context of use. Perhaps some elements from the prototype bamboo drone – such as the use of widely available smartphones as both the flight controller and the route planner (a stand-alone system), along with easy repairability in the field – could be beneficial for drones to be used in Sierra Leone.

Educating students about ethics along with technology will be key, as this newfound power will require enhanced responsibility to not only reduce the risks of misuse but to enhance life for those beyond the drone operators. Ideally, the lucky few students that are able to attend university could one day become ethically and technologically informed advocates for the many poor and disadvantaged citizens in Sierra Leone.

There are a multitude of risks in using drones for mapping in Sierra Leone. The most critical is that more data than is strictly necessary for defining land boundaries will be collected, and that this data will be used in ways which are not in the best interest of the citizens. For example, aerial photos of plantations show what crops are being planted, photos of villages show how many buildings are present giving clues to the number of inhabitants, and photos of the land could indicate potential mining sites. It seems likely that powerful stakeholders could gain access to this multitude of data, and that it would be used against the landowners. Alternatively, drones could be useful in the hands of Sierra Leone's citizens and landowners – for example, giving farmers an overview of their crops. But education, infrastructure, and investment will be required before this will be possible.

Note

1 The author visited the Zipline operation in rural Rwanda in early 2020. Drones were launched like clockwork – at this point the technology appeared quite reliable and their use routine. Benefits to the surrounding areas appeared minimal, and only a handful of jobs seemed to have been established inside the fenced-off facility.

5 The Spiritual Drone

5.1 The Ethical Phase

The spiritual drone is an artwork (see "Art") and a speculative design (see "Speculative Design") (Figure 5.1). It is an experiment in creating a non-drone/drone, a critique of the high-tech, and a response to most drone's commercial and data collection motives. It *is* a drone in that it flies (or it appears to fly), it has motors and rotors, a drone-like shape, and a payload. It is *not* a drone in that it does not fly freely or autonomously but is directly bound to a human: it is flown like a kite, which has been said to still be innocent, virtually unsullied by war and commercial interests (Choi-Fitzpatrick, 2020). The cord allows the operator of the drone to be clearly visible, enhancing accountability and eliminating the unintelligibility of a wireless connection. Through the cord, the drone becomes an extension of the operator – directly connecting them with the technology in the sky. The spiritual drone does not carry commercial cargo or sensors, making it ineffective for economic activities or data collection. And it is not high-tech: it is made of mostly unprocessed, locally sourced, and "waste" materials. The sticks for the frame were found in a pile of brush near the author's home in Odense, Denmark; the clay comes from the nearby coastline of Nyborg. The motors were recovered from the electronic waste bin at the university, along with the electrical power/control cord. The feathers were sourced from the UK, and the sage was purchased locally. In these ways, the spiritual drone is both a drone, and a non-drone.

Creating the spiritual drone has led to the identification of some additional ethical considerations: for example, the role of spirituality in human values, and the place for fun, humor, and novelty. The values discussed in the earlier chapters, and those most often cited in the VSD literature, do not include direct consideration of religion even though it can be a defining characteristic of one's ethical landscape and decision-making. This is a shortcoming of the ethical framework for the design of drones used in

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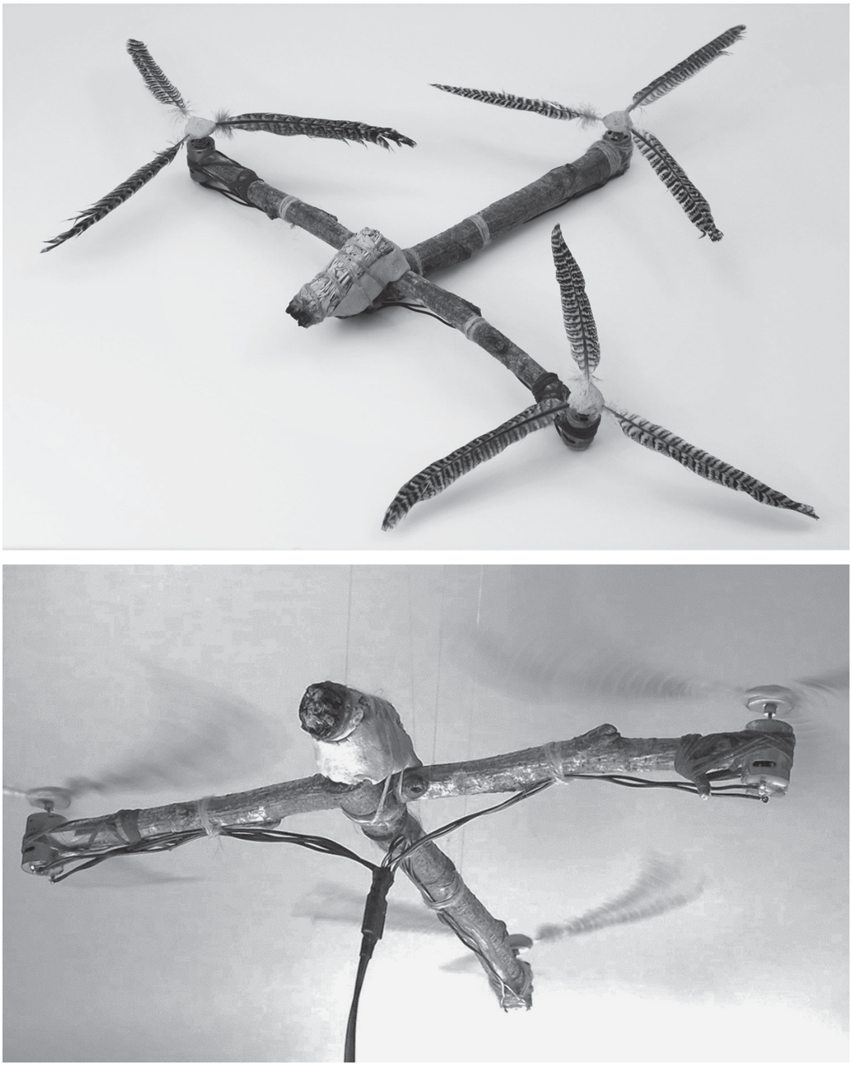

Figure 5.1 The spiritual drone is an artwork that explores what drones are, what they are not, and what they could be (top). The frame is made from raw wooden sticks, the motors are electronic "waste", and the rotors are made of feathers. A long power cord connects the operator with the drone, directly connecting the human to the technology in the sky. The spiritual drone "flying" (bottom). It carries a smoldering bundle of sage at the front to spread cleansing smoke throughout a community.

Source: Artwork and images by the author.

public healthcare as well – it is of limited relevance in a religious context; for example, when assessing a drone to be used for the transportation of birth control or abortion pills (see "Ethical Frameworks"). And although the diffuse concept of beneficence is often cited, fun, humor, and novelty are seldom mentioned as key human values to be upheld.

5.2 The Social Phase

5.2.1 Context

The spiritual drone was developed shortly after the author submitted their PhD thesis about the value-sensitive design of uncrewed aerial systems. This academic work had been intensely focused on designing "good" drones for years, and in working in a methodical and theoretically grounded way. The author desperately needed a break from both of these, and found an outlet in making art. In fact, at the time it was not an activity they expected to write about – only a form of catharsis from the analytical. At the time, the author felt disenfranchised from technology in general, and from drones specifically – as most of their life, they had believed that technology was the key to making the world better, and that by making technology they were in some small way contributing to positive changes. But the results of the PhD studies suggested that technology was a multifaceted and nuanced undertaking which could benefit some, yet often harmed others. The author felt deceived by the narrative of "keep calm, engineers will save the world".[1] They were sad, and angry. They wanted to question and subvert drones. They also wanted to break things (see Figure 6.3). The spiritual drone was one of the results of this state of mind and this context. Although it was created mostly as a form of personal catharsis, it is included in this book in the hopes that it can spark discussion and a questioning of existing paradigms within drone engineering.

The spiritual drone artwork is officially titled *Electromechanical Sage Bird*, and it debuted in 2021 as part of the "Perverted Engineering" exhibition in Odense, Denmark. Later that year, it was accepted into the Georgia Tech (USA) Robotics X Art exhibition ("Robotics X Arts Exhibition: Opportunities and Issues in Robotics Applied in the Arts," 2021) and is on permanent display in the online gallery.

5.2.2 Use Plan

- The bundle of sage is lit on fire.
- The drone is flown like a kite – using the tether to steer and set the altitude – over a community.
- The sage smoke cleanses and blesses the community and the environment.

5.2.3 Stakeholders

Direct stakeholders include the artist and collaborators, the local culture fund, and those that attended the art exhibitions where it was shown. More broadly, the work has impacted colleagues, engineers, other artists, and nature.

5.2.4 Empirical Investigation

No formal empirical investigation has taken place in developing this artwork. Instead, intuition, emotion, and subversion were the guiding forces.

5.3 The Technological Phase

5.3.1 Description of Materiality

The physical embodiment of the spiritual drone is described in this section.

5.3.1.1 Size and Configuration

The spiritual drone is 50 cm wide, 45 cm long, and 12 cm high; it weighs 700 grams.

5.3.1.2 Exterior

The drone has no added external embellishments.

5.3.1.3 Materials

The drone's frame consists of two raw wooden sticks bound together in a "T" configuration with flax fibers; leather strips secure the motors to the frame. The propellers are made of bird's feathers. Clay is used at the front of the drone to hold the bundle of sage (the payload), and on the propeller hubs to hold the feathers.

5.3.1.4 Payload

At the front of the drone, a clay holder supports a bundle of dried sage leaves.

5.3.1.5 Power System

Three 6-volt, brushed DC (direct current) motors are mounted at the ends of the frame; these turn the feather rotors directly. The drone is powered by a sealed lead acid (SLA) battery via a long power cord: it is a tethered drone, and the battery remains on the ground with the operator.

5.3.1.6 Sensors

The drone has no sensors.

5.3.1.7 Control

The long power cord is used to fly the drone like a kite.

5.3.1.8 Support Systems

Fresh sage is required occasionally, as is a battery charger.

5.3.1.9 Summary of Specifications

- Width – 50 cm
- Length – 45 cm
- Height – 12 cm
- Weight – 700 g
- Power – 60 watts
- Payload – dried sage leaves
- Control – flown like a kite using the power cord

5.3.1.10 Performance

The spiritual drone artwork does not fly, but is held aloft with clear strings in order to simulate flight.

5.4 Should This Drone Be Built?

Yes.

Art is a space to experiment with alternative conceptions of many things – including technology – to initiate debate, and to subvert and question dominant paradigms (see “Art”). Artistic outputs such as exhibitions, performances, and objects, could be useful alternative or supplemental outputs to traditional scientific research (i.e. conference papers, journal articles, academic books). See, for example, the “Thinking head” project, which set out to develop a virtual autonomous conversational agent and that sparked the book *Robots and Art: Exploring an Unlikely Symbiosis* (Herath & Kroos, 2016). The project included an artist, a cognitive scientist, and a roboticist in an interdisciplinary collaboration with outputs that included artistic performances with humans and robots, which engaged the public and reached those in multiple research fields.

Similarly, the spiritual drone acted as a thought experiment made physical. It was not constrained by economic requirements, or even by the technical requirement that it should fly. However, its reach is hard to measure, and its impact on real-world drone engineering diffused at best. Commercially produced drones (i.e. non-non-drones) are directly changing the world at large, which makes it difficult to compare the two.

Still, perhaps some of the ideas pursued in the spiritual drone could find their way into commercial technology. For example, the development of drones for spiritual reasons, or for fun; a drone that gives something (cleansing smoke), rather than taking something (photos, data). It could inspire an uncompromising approach to environmental sustainability and human health throughout the drone's lifecycle through the use of local and safe materials. And it could highlight the benefits of tethered drones, which by their nature enhance intelligibility and accountability.

Note

1 This was the slogan the technical faculty communications department at my university had for a year, with the phrase printed on t-shirts, and on postcards over the image of an electric wind turbine. Another notable and questionable slogan: "Science without engineering is just philosophy".

6 The Theory, Methodology, and Practice

6.1 Embodied Values of Technology

The embodied values approach to technology states that technologies such as drones are not ethically neutral – not simply material objects – but that they enable or limit certain actions, and these actions have moral consequences. Technology enhances one's capabilities, such as the ability to see from above using a drone, which has implications to ethical considerations such as privacy. The embodied values perspective is in contrast with an earlier paradigm – one which is still commonly held in engineering – which claims that technology has no ethical dimensions. This is referred to as technological neutrality (Verbeek, 2008).

The embodied values approach can be illustrated through the gun debate in the United States. Anti-gun advertising campaigns have claimed that "guns kill people", while the pro-gun lobby has responded with "guns don't kill people, people kill people" (Vermaas, Kroes, Light, & Moore, 2007). The latter argument puts the responsibility for the use of technology – guns in this case – with the user, while the former puts the responsibility on the gun technology itself. In the embodied values approach, the user, the designer or engineer, the technology itself, and the context of use each play a role in what values are upheld (or diminished). Therefore, the user – as well as the gun, its design, and where and under what circumstances it is used – plays a role in the actions it can perform and in the ethical implications of these actions. The designer or engineer has significant influence on this interaction; for example, they may design an automatic, semi-automatic, or manually loaded weapon, with a long or short barrel, with or without a fingerprint reader, and with or without a trigger lock. Each of these decisions will facilitate different actions, with automatic weapons being highly effective at killing, short barrel weapons being easy to conceal, and those without fingerprint ID and trigger locks easier to operate by non-authorized users. The engineer may also consider the intended (and unintended) contexts of use, which could be at a shooting range, or at a school.

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Table 6.1 A non-exhaustive list of human values that are often relevant within technological design

Human value	*Description*
Human welfare:	
Physical welfare	Bodily well-being, safety (prevention of harm), physical security
Psychological welfare	Mental health, including stress and calmness
Material welfare	Physical circumstances, including economics, jobs, ownership, and property
Privacy	Determining what information can be communicated to others
Justice	Rightness, fairness in both process (procedural justice) and outcomes
Trust	Expectation of goodwill; ability to be vulnerable; includes elements of explicability; may include aspects of misuse, as well as dual-use considerations
Human autonomy	Freedom to think or act in order to uphold values and achieve goals
Informed consent	Knowledgeable and voluntary agreement to participate
Accountability	Traceability from action to actor; related to responsibility and explicability
Identity	Being able to be one's true self
Environmental sustainability	Protection of the natural environment

Sources: Friedman et al. (2013) and Miller (2021).

6.2 Human Values

Human values are those things which a person or a group of people find fundamentally important in their lives and to their way of being (Friedman & Hendry, 2019)[1]; Table 6.1 lists several human values that are often important in technological design. Many human values – situated in specific contexts – have already been introduced in The Ethical Phase of the prototype drone chapters. Some human values there included human welfare, safety, security, privacy, justice, and trust. In this section, human values are presented in general terms so that the VSD method can be utilized outside of the specific contexts detailed earlier.

The list in Table 6.1 is non-exhaustive, and some human values may not be included – such as spirituality or humor, mentioned earlier in The Spiritual Drone. Human values often overlap, intersect, and converge, and can manifest themselves in very different ways in different cultures and contexts. Therefore, the human values in the list may be useful as a "top-down" starting point – especially for those unfamiliar with using ethics in design – but should always be considered contingent and awaiting confirmation from stakeholders. Alternatively, "bottom-up" data can be collected from stakeholders without any preconceptions about what their values might be (see "The Social Phase Methods"). In practice, an abductive research design (see "Research Design") can be used to combine these two approaches, and the "bottom-up" and "top-down" data compared and synthesized.

The term "value" is often associated with economic value – that is, the selling price of an item in the marketplace. Economic value is relevant to the social aspects of VSD as a contextual consideration, as well as to material aspects of human welfare including ownership, property, and jobs. But the VSD approach places emphasis directly on human flourishing unlike most market-driven approaches, which prioritize economic value over all else. It is both a strength and a weakness of VSD that economic value is not given a special place in the theory. A benefit of this approach is that it shifts the aims of technological development back to human aspects – after all, the aim of technology is to increase human capabilities. A downside of the approach is that it may be more difficult to incorporate VSD into a market economy, which is driven by the profit motive. In some cases, these viewpoints will align – for example, designing a drone that uses less electricity will be beneficial from an environmental perspective and be attractive in economic terms as well since it will cost less to operate. However, in many cases, there will be conflicts between a human values-centered approach and profit maximization. Arguably, VSD puts things back in their proper order: as one scholar has stated: "the purpose of the economy is to serve the people, and not the people to serve the economy" (Max-Neef, 1991).

Human values are not the same as preferences; preferences are those things which a certain individual might like better, while human values are fundamental beliefs which could be universally accepted as important. "Establishing that something is a value or professing it to be valuable means not only claiming that it is valuable to me but also that it is or should be of value to others" (Van de Poel, 2009). For example, one can prefer the color blue, but another may prefer the color red – either preference is equally valid to each individual. But both people – and people more broadly – will value and find it important that their bodily welfare, health, and safety is preserved as well as that of those around them.

An important aspect of human values is their universality – or, perhaps, their *lack* of universality and contextuality. Philosophers have long debated if all humans share the same values, or if values depend on factors such as context and culture. There are a variety of positions. One position is that human values are fairly universal, and that all people share some version of these values. The list of human values often implicated in technology design (Table 6.1) implies that all of these values are relevant to all people. So, a drone designed for use in Denmark, as well as one designed for use in Sierra Leone, should both consider the human value of privacy. These two values may manifest themselves differently in these two different contexts, but they are universally held.

Another position is that human values are not universal, or that they manifest themselves so differently in different contexts that they cannot be meaningfully compared. Along these lines, some philosophers refuse to list or identify any human values. Human values may be described in a way which is so abstract that they may appear to be universal, but their definitions are so diffused that they are not particularly useful. For example, beneficence, human welfare, and justice are very high-level concepts which only gain meaning when considered within a given context.

It may be difficult for stakeholders to articulate their values since they are so fundamental that they are often not discussed. Methods for value identification are described in the social phase methods section, and include special approaches to empirical investigations which help bring stakeholders' values to the surface. The values of the engineer(s) or designer(s) – referred to as designer values in the literature (Friedman & Hendry, 2019) – should be made explicit in a VSD process as well, since they represent the values of stakeholders that have direct influence over the technology. The author's values – which were often invoked in the design and development of the prototype drones in this book – are discussed in the chapter about the engineer, in the designer values section (see "Designer Values").

6.2.1 Human Welfare

Human welfare is the preservation and flourishing of people's physical, psychological, and material welfare (Friedman & Hendry, 2019). Physical welfare includes one's bodily health – safety, and the protection of the body from disease and ailment, as well as physical thriving. Psychological welfare concerns mental health and well-being, including considerations such as stress, anxiety, and depression – but mental flourishing as well, including calmness. Material welfare refers to people's physical circumstances, including their economic situation, as well as work-related concerns including employment or jobs. Human welfare is perhaps one of the most important human values, and considerations of the preservation of – and enhancement to – human welfare through the ethics of drone design were demonstrated throughout the prototype drone case studies. The Danish healthcare drone would have a multitude of impacts to human welfare (see "Human Welfare"), including the physical health of patients whose blood samples are transported, physical safety of those overflown by the drone (see "Safety"), a psychological impact on calmness (see "Calmness"), and constitute a change in people's jobs (see "Jobs"), just to name a few.

Material welfare is related to the human values of ownership and property – the right for people to possess material goods, property, and land rights, as well as ownership of non-physical entities including data. Ownership may seem straightforward, but many modern technologies blur the boundary between a product that one owns outright and a service; for example, some smartphones require the owner to create an account with the company in order for the product to function, and the usefulness of the smartphone depends on updates and compatibles software being made available sometimes years after purchase.

6.2.2 Privacy

Privacy is the ability for people to determine what information about themselves may be shared with others (Friedman & Hendry, 2019). Privacy is related to aspects of human psychological welfare, such as through the chilling effect (see "Privacy"), as well as the preservation of data or information about one which relates to ownership and property. Privacy can be conceptualized as the preservation of information about oneself, or more generally as necessary for human dignity (DeCew, 2018). Although privacy is usually conceived of as limiting the spread of information, giving others access to private information is a way in which we cultivate trust and the development of meaningful relationships.

6.2.3 Justice

Justice is the far-reaching human value of rightness and is related to the idea of fairness. One conceptualization of justice has four distinct aspects: justice for individuals, justice as an obligation placed upon others, justice and impartiality (such as the consistent application of rules), and justice and human agency/autonomy (Miller, 2021) . Distributive justice points to the equity of how goods and services, or more generally as how beneficial and harmful impacts, are spread throughout a population. Procedural justice entails the fairness (or lack) of processes; for example, a VSD process, which includes various stakeholders, could be considered a more procedurally just form of drone development than one which includes only powerful stakeholders. Freedom from bias is a type of justice of impartially. This includes social and technological bias of individuals and of groups. For example, if the search and rescue drone's AI is only trained to detect adults, this would be a form of technological bias that would harm non-adults, that is, children. Also related to justice, universal usability is the ideal that a technology should be usable by all people, regardless of ability or disability. There are obvious practical limitations to achieving this aim considering the multitude of knowledge, skills, physical abilities, and human characteristics that exist; still, it is an important aim of VSD to consider these aspects in design.

6.2.4 Trust

Trust is the expectation to experience goodwill from others (Friedman & Hendry, 2019), and the willingness of one to be vulnerable to others in the hope that they will respond in good faith (McLeod, 2020). Trust allows one to depend on others but also puts one at risk since they become vulnerable in the situation. Governments, institutions, companies, and groups may engender trust or cultivate mistrust through their systems, their actions (or inactions), or the actions of their members.

6.2.5 Human Autonomy

Human autonomy is the freedom to think or act in the absence of obstacles, barrier, or constraints (referred to as negative freedom), or in ways which allows for the achievement of one's goals, to uphold one's values, and/or fulfill one's desires (Carter, 2021; Friedman & Hendry, 2019). This freedom requires that others do not have – or chosen not to exercise – authority or control over this personal autonomy (Westlund, 2018). Western societies place a lot of importance on the concepts of autonomy and freedom, but it should be noted that complete autonomy would entail an isolating lack of obligation to anyone or anything – and likely interfere with the autonomy of others to exercise their values. A related issue is when the freedom of one to make their own decisions interferes with the freedom of others to exercise their autonomy. Human autonomy is further complicated because both the *intention* of the agent as well as the *consequences* of the agent exercising their autonomy are relevant. Human autonomy presumes that *free will* – a kind of catch-all term for control over one's actions – is a reality, although there are philosophical arguments (O'Connor & Franklin, 2022) and empirical evidence (Sapolsky, 2017) that at least call this assumption into question.

6.2.6 Informed Consent

Informed consent is the securing of voluntary agreement to participate in, be subjected to, or have data collected about one, given knowledge of the potential outcomes. Hence, informed consent is related to justice, trust, and privacy. Informed consent is relevant in contexts such as experiments involving human subjects, as well as for data privacy in information technologies such as web browsing cookies/data storage and tracking (Friedman & Hendry, 2019).

6.2.7 Accountability

Accountability is the ability to trace actions and outcomes back to a specific person, group, or institution. Accountability plays a key role in explicability, and in ascribing responsibilities (giving praise or placing blame); for more information, see the section on responsibility ("Responsibility"). As discussed earlier, engineers and designers play a key role in the embodied values paradigm and therefore which values technologies support or diminish. Arguments for why engineers and technology developers should abandon the idea of technological neutrality and voluntarily take on an increased level of responsibility are provided in the section on responsibility (see "Responsibility").

6.2.8 Identity

Identity is the understanding of who one is, along with how one is perceived by others (Friedman & Hendry, 2019). In terms of human flourishing, identity entails the ability to be one's "true" self and to pursue self-actualization – "to be the best you that you can be".

6.2.9 Environmental Sustainability

Environmental sustainability is about both the preservation or absence of harm toward the natural environment, as well as the nurturing, enhancement, and restoration of it. Environmental sustainability contains elements of justice since non-renewable resources used or pollution created today will impact future generations. There are various conceptions of the inter-relationship of humans with non-human animals, fish, insects, plants, mushrooms, mountains, rivers, etc. Anthropocentrism is the view that humans are exceptional and should be placed at the top of a hierarchy above all other animals and nature; it proposes that animals and nature are useful only to the extent they can benefit humans. Although this is a common viewpoint in society, it is a position that few contemporary philosophers would argue for. Zoocentrism is the view that at least some animals deserve moral standing ("Speciesism,") as ethical subjects and deserve some level of respect and consideration. Sentientism places importance on the presumed sentience of an animal – those animals that are deemed sentient should be granted special ethical consideration ("Sentiocentrism," 2022). Zoocentrism and sentientism are commonly held views in the western world and are sometimes utilized in legislation.

Biocentrism is more inclusive and does not require any certain capabilities; it is the view that all living beings should be taken as part of the ethical community. Ecocentrism is the perspective that humans are an inseparable part of nature, with all aspects of the human, non-human animal, sentient, and non-sentient (rocks, rivers, etc.) having moral standing. In this view, the protection of nature is the protection of oneself. It could be argued that due to our immense power over the natural world, humans have an elevated obligation to protect and nurture it. Environmental sustainability has become an increasingly important aspect of engineering and is now well-established with various design approaches and analysis tools being utilized including design for end-of-life (EoL), environmental impact potential assessment (Iversen et al., 2020), and lifecycle analysis (LCA), to name just a few.

6.3 Value-Sensitive Design

Value-sensitive design was briefly introduced at the beginning of the book (see "Introduction to Value-Sensitive Design"), and the previous drone case studies showed the application of the value-sensitive design methodology in the development of prototypes drones for healthcare, search and rescue, education, and spirituality. In this section, the value-sensitive design method is described in general terms so it can easily be applied to new cases.

Again, value-sensitive design (VSD) is an applied ethics approach to the development of technology which puts human values at the forefront – it is *sensitive* to human values. Human values are those things which "a person or group of people consider important in life" (Friedman et al., 2013); some human values have been described in the previous section, and listed in Table 6.1.

Value-sensitive design consists of three main phases: the ethical phase, the social phase, and the technological phase (see Figure 1.2). In the ethical phase – which is often carried out by ethicists and philosophers – the ethical impacts, human values, and if/how a technology supports or diminishes human flourishing are considered. In the social phase – typically done by social scientists – the interactions of people with the technology, the stakeholders, and contextual aspects (i.e. location, culture) are considered. In the technological phase – often carried out by engineers and designers – new products, services, etc., are developed. The aim of VSD from the perspective of the engineer is to utilize inputs from the social and ethical considerations to create better technologies. The VSD process is iterative and often a series of experiments and prototypes are used to test various hypotheses including technological performance, social interaction, and impacts on human flourishing.

In some cases, the VSD method is applied in a narrow way, where external constraints are taken as given and the design is optimized within those constraints. In other cases, VSD is applied in a broad way, where the scope of the analysis includes the questioning and possible modification of external conditions and where a total re-conceptualization or even discontinuation of the design is possible. In this book, the latter approach is taken – for example, how the healthcare drone and its design could impact the shifting of investment in the Danish healthcare system (see "The Healthcare Drone"). Critically, the broad application of VSD includes meta-ethical considerations: Should this drone be built? If so, how? If not, why not?

A value-sensitive design can start with any of the three phases: it could begin with the technological phase, prompted by new capabilities brought forth by engineering – such as drones. It might be sparked by the social phase from an observation about culture, society, or human behavior. Or it could be driven by the ethical phase, such as through an exploration of philosophical ideas or conceptions of human flourishing. Most of the VSD analyses that have applied the methodology to develop real technologies have started with the ethical phase, conceptualizing human values, etc.; then, about half proceed with either the technological or the social (Winkler & Spiekermann, 2021) .

In this book, the ethical and the social phase were taken first in the development of the prototype drones: human values were front-loaded, and a certain context and use-case were considered, along with some technological scoping (i.e. drone technology). But any sequence of the VSD phases can be successful, being seen as "top-down" – from conceptual to material, or "bottom-up" – from material to conceptual. In practice, all of the phases are so inter-related that they can be developed in parallel: considerations of technological possibilities, social impacts, and ethics interplay in a highly dynamic way. This is indicated in the VSD process graphic, where "interactions" are present at the overlaps of all of the phases (see Figure 2).

Although it is positioned and most useful as a prospective (i.e. forward-looking) approach to technological development, VSD can also be used to retrospectively analyze existing technologies. For example, a retrospective VSD analysis by the author argued that the purported values of the humanitarian robotics organization WeRobotics – to preserve and enhance human physical, psychological, and material welfare, and environmental sustainability – were supported by the prototype drone they operated in the Amazon of Peru. But, there were risks to jobs, infrastructure investment, and quality of care due to the remote nature of drone delivery compared with in-person hospital visits (Cawthorne & Cenci, 2019). After this analysis, a forward-looking proposal was made for a new drone design that would minimize some of the risks.

6.3.1 The Ethical Phase Methods

Empirical sources for human values are abundant when one knows where to look. Beyond primary data collection methods that will be described in the next section, secondary data can also be used as a starting point for identifying relevant human values. For example, the United Nations Sustainable Development Goals (UN SDGs) ("Sustainable Development Goals," 2023) outline 17 high-level aims for global development including eliminating poverty and hunger, reducing inequalities, taking part in sustainable production and consumption, enhancing peace, and creating strong and justice societies. Countries often have technological strategy documents, as well as agendas for their future economic and social development, which can be interpreted as values. Africa has Agenda 2063, which is relevant for analysis of the drone in Sierra Leone. This far-looking plan aims to create "the Africa we want" and includes prosperity, political integration, the upholding of Pan Africanism and African Renaissance values, human rights, democracy, and peace ("Agenda 2063 – The Africa We Want," 2023).

Many companies and nonprofit organizations have mission statements, corporate social responsibility (CSR), and/or sustainability reports that discuss the human values they proclaim to support. For example, the Danish toy company LEGO's values include supporting the development of children, addressing climate change, providing a good working environment for employees, taking in feedback from stakeholders, and being engaged with the local community (*Sustainability Progress Report*, 2021). Of course, the marketing aspects of CSR reports should be taken into consideration, but still, they can be a useful starting point to uncovering key human values at stake in a VSD process. Recall that a risk of over-reliance on empirical data to inform values can lead to the naturalistic fallacy (see "Stakeholders"), and that it is possible for stakeholders to have values which should not be supported.

There are also many non-empirical sources for identifying human values. The conceptual work of philosophers and ethicists is non-empirical; they involve abstract thinking about human flourishing, right and wrong, and good and evil. This work has been going on for thousands of years in all areas of the world, but its abstract nature is difficult to systematize, and a criticism of VSD is that it is not always clear exactly how the ethical phase of the analysis is performed (Manders-Huits, 2011). One way to address this limitation is being explicit in the normative perspective(s) used (see "Normative Ethics").

Normative ethics is a conception of how things *should* be, from an ethical perspective – what is ethically good, a moral ideal or aim. Normative approaches are used to guide action, what type of person to be, or as a lens through which to view a particular ethical problem or situation. Different normative frameworks may guide one to perform similar actions, but for different reasons; sometimes, they will guide one to different actions. Given that normative diversity exists (i.e. different people have different values – see, for example, Cuppen, Pesch, Remmerswaal, and Taanman (2019) – the normative stance(s) taken in VSD research should be considered and can be made explicit.

There are three main approaches to normative ethics in the western tradition: consequentialism, deontology, and virtue ethics. Consequentialism puts focus on the result – or consequences – of actions, the outcomes (Sinnott-Armstrong, 2019). It is a normative perspective that guides actions; in order to decide which actions to take, one should consider the likely consequences of those actions. Actions which lead to morally good outcomes should be taken; those that lead to morally bad outcomes should not. The consequentialist ideal of *human flourishing* comes about as the result of these morally good outcomes. This is in contrast with normative theories where the focus is placed on *intentions*, and the *type* of person one should be, such as in virtue ethics (see "Virtue Ethics"). Consequentialism can be applied on an individual basis but is often employed in a broad context where the overall impact on humans (and possibly to nature as well) is considered. Many engineers utilize a consequentialist normative perspective and are most concerned with actions and the realized effects of those actions.

A well-known type of consequentialism is utilitarianism. Utilitarianism states that what is morally good are actions which lead to the most good – or *utility* – for the most people (in some versions, this includes all lifeforms that are able to experience pleasure or pain) (Sinnott-Armstrong, 2019). The utilitarianism conception of human flourishing is in maximize the overall good – sometimes stated as overall happiness – in the world. As in consequentialism, one should not *only* be concerned with their own happiness, but with the happiness of others as well. Happiness should be considered impartially – your own happiness counts just the same as that of anyone else. Utilitarianism seems to require a complicated type of moral calculus each time one plans an action – where the pleasures and pains of everyone is accounted for. But many utilitarians admit that there are practical limitations to such a decision procedure, and instead state that maximizing utility is simply the criteria for what is morally good.

Long before they were commonplace, utilitarian arguments were made that supported equal rights for women, including the right to vote and to an education (Driver, 2014). It was argued that women – constituting half of all people – could experience significant gains in happiness by having access to voting rights and education, while some men would experience only relatively small losses in happiness in denying them these opportunities (and that deriving pleasure from limiting someone else's opportunities was a bad type of pleasure – see the section on "Virtue Ethics").

Viewed from a utilitarian normative perspective, the prototype Danish healthcare drone is morally good to the extent which its development and use would result in an increase in overall utility or happiness in the world. It seems likely that patients who benefit directly from the increased responsiveness of drone delivery would experience some incremental improvement in their well-being compared with the current transportation method, while a larger number of people could be slightly disturbed or inconvenienced by the drone's presence (just to take two impacts into consideration). Therefore, from a utilitarian perspective, it is critical to maximize the number of people benefiting, and to benefit them as much as possible, while minimizing the number of people harmed, and minimizing this harm.

Deontology is the normative approach where good actions are those that align with moral norms (Alexande & Moore, 2020). Deontology deals with duty, and with which choices are ethically required, permitted, or forbidden. In deontology, human flourishing is achieved with a focus on responsibility and exemplifying the moral standards *in a given context*. Deontology is often contrasted with consequentialism, which brings up key features of each. Deontology says there are certain actions that, even if they were to bring about an overall increase in good consequences, are wrong and therefore should not be performed: "the right is said to have priority over the good", unlike in consequentialism where such actions could be morally *required*.

For example, if a drone is developed for spying and is so competent at doing so that none of those surveilled detect it (and do not learn of it in other ways), and the data gathered from the drone can be useful or profitable (thereby increasing utility), then this drone is morally permissible. In deontology, the ends do not justify the means – actions that violate moral norms – even if these actions would give rise to benefits for some – are simply impermissible. Spying on people, even if it leads to an overall increase in utility, is not aligned with the moral norm that privacy must be respected, which exists in most contexts, and is therefore forbidden.

Viewed from a deontological normative perspective, the prototype Danish healthcare drone is morally good to the extent which its development and use would support the local moral norms. Important norms in Danish healthcare are those of universal and fair access to health services. At Ærø, there is a norm of calmness, and in Denmark in general there is a norm that privacy must be respected. Therefore, from a deontological perspective, the drone is morally good if it can support the preservation and enhancement of these norms.

Virtue ethics is about the development of one's moral character; it provides guidance for aspects of one's nature to cultivate (virtues), those to avoid (vices), and for the type of person one should strive to become (Hursthouse & Pettigrove, 2022) (Vallor, 2016). Emphasis is placed upon intent and on way-of-being, rather than on the (sometimes unpredictable) consequences of actions. Virtue ethics has been described as "practical wisdom" – something that is engrained in a person, and which must be exercised and experienced in daily life – rather than calculating benefits and risks or following rules (Vallor, 2016). A virtue is a positive character trait, one of entrenched excellence. Being virtuous is a mindset and a way of being; the virtuous person thinks, acts, feels, and chooses in ways that cultivate positive characteristics. The virtue ethics version of human flourishing is a world where people develop and cultivate a multitude of positive character traits.

For example, a virtuous engineer would not build a spy drone to collect data on people without their knowledge or consent. The engineer – in both their private life and in their work – cultivates the virtues of honesty and justice (among others). Spying is deceitful and thereby dishonest. And spying is not fair, thereby it is unjust. Creating such a spy drone would not align with the engineer's virtues and should not be built. Many of the virtues support the related value of responsibility (see "Responsibility"). To see this approach put into action, see the section on designer values ("Designer Values").

Virtue ethics is thousands of years old, but it has recently seen a resurgence within technology ethics as a useful and flexible approach to addressing the fast-pace and complexity of modern life. In the book *Ethical IT Innovation*, Spiekermann utilizes a virtue ethics approach, conceptualizing it as "wise leadership" (Spiekermann, 2015). Vallor (2016) has introduced the techno-moral virtues; making good technology means making technology which cultivates the following virtues:

- Honesty – respecting the truth
- Self-control – managing our desires
- Humility – knowing what we do not know
- Justice – upholding fairness
- Courage – intelligent fear and hope
- Empathy – compassionate concern for others
- Care – loving service to others
- Civility – pursing a common cause
- Flexibility – skillful adaptation to change
- Perspective – maintaining the moral whole
- Magnanimity – moral leadership and nobility of spirit
- Moral wisdom – practicing complete virtue

6.3.2 The Social Phase Methods

There are a multitude of empirical (i.e. derived from experimentation or observation) social science methods which are useful in the social phase of a VSD process. Empirical methods used in VSD have focus on human values and stakeholder engagement. Some of these methods are:

- Value-oriented semi-structured interviews (Friedman & Hendry, 2019)
- Value-oriented coding of qualitative data (Friedman & Hendry, 2019)
- Focus groups using an anticipatory (i.e. forward-looking) methodology (Macnaghten, 2017)
- Co-design workshops with stakeholders (Yoo, Huldtgren, Woelfer, Hendry, & Friedman, 2013)
- Rapid ethnography (Millen, 2000)
- Value-oriented prototypes (Friedman & Hendry, 2019)
- Value-sensitive design envisioning cards (Iversen & Cawthorne, 2022)

6.3.3 The Technological Phase Methods

Traditional engineering methods are relevant in VSD; for example, value-sensitive drone design still relies on aerodynamic lift and stability calculations to ensure the drone can fly and be controlled, calculations of the structural design utilizing material properties to ensure the drone will not break under the conditions of flight, and calculations of motor, propeller, and battery choice to ensure the drone can fly for the duration of the mission (Cawthorne, 2020). In addition, there are VSD-specific methods that enhance the technologists' ability to integrate these technical approaches together with social and ethical considerations. A very useful method is translating values into design requirements, where abstract human values and contextualizing social norms are systematically converted into technical requirements (Van de Poel, 2013). Ethical frameworks (see "Ethical Frameworks") are another tool to support ethically informed technological design.

The traditional methodological approaches in engineering, that is, the positivist world view, quantitative research approach, and deductive research design may not be the best fit in a VSD analysis. At the least, an appreciation for the other approaches is beneficial. Technological methods that are used by engineers are still appropriate in a VSD analysis, but the scope of the considerations will be much broader, and the emphasis will not be on the technology in and of itself, but on how the technology can enable meaningful actions, help to rebuild nature, and support human flourishing.

Importantly, engineering, design, and other technological methods tell us what we *can* do – that is, what it technologically possible. However, a consideration of the social context and of ethics are necessary to determine what we *should* do – that is, what is morally good:

> Technology without ethics allows us to do stupid things in a very clever way.
>
> (Baier, 2017)

6.3.4 Value Conflicts

Dealing with technological design conflicts is at the core of being an engineer or designer, and value conflicts play a similar role in VSD. Value conflicts occur when different stakeholders hold different values. Value conflicts may be rooted in "normative diversity" – for example, where different stakeholders hold different conceptions of human flourishing. This can include differences in how various stakeholders prioritize values. For example, in the Netherlands stakeholders that lived near a proposed natural gas extraction site valued their health and environmental preservation, while politicians in The Hague and gas companies that wanted to extract the natural gas valued energy independence and material welfare respectively (Cuppen et al., 2019). Value conflicts can emerge when crossing borders; for example, drone developers from Denmark may hold very different values than those held by stakeholders in Sierra Leone, and determining which values are upheld by the technology is critical (see "The Sierra Leone Education and Mapping Drone"). In the design of the Danish healthcare drone, the values of potentially more meaningful human work that could be achieved via active drone piloting – which depended on livestreamed video – was in conflict with the preservation of citizen privacy. To address this conflict, a new technological solution was developed: a closed camera system which only steamed video when the drone is flying, and only gave low-resolution images at low altitudes – yet which the human pilot could still navigate by (see "Sensors"). This is an example of an innovation approach, where – through innovation – value conflicts are eliminated by developing a new technological solution (Van de Poel, 2009). Ideally, value conflicts can be addressed in such a way that compromises are not needed, and technologies which create "win-win" situations are developed.

VSD makes use of inputs from a multitude of stakeholders; this makes the likelihood of value conflicts high, and means that the task of dealing with them will be much more complex than an engineering-only approach with a more narrow scope. Still, rather than ignoring or avoiding conflicting human values, VSD attempts to address these in a systematic and transparent way. In the end, it might be impossible to please every stakeholder, but taking their input and addressing it in an explicit and proactive way is a procedurally just approach.

6.3.5 Moral Overload

Value conflicts can become overwhelming for the engineer or designer, leading to moral overload. Moral overload is the experience of being confronted with ethical dilemmas where multiple, seemingly incompatible requirements and human values should be preserved simultaneously (Van den Hoven, Lokhorst, & Van de Poel, 2012). At times, it can feel like doing anything will cause a bad outcome for some stakeholder, or at least create potential risks.

However, engineers and designers should remember that there is an opportunity cost to *not* acting. There are situations where technology may be able to create new solutions which preserve human values that were impossible to uphold simultaneously before (Van de Poel, 2009). For example, if one really enjoys eating meat but thinks it is wrong to eat animals, then developing an "impossible" meatless burger alternative could lead to a win–win situation where both values can be upheld at the same time. And, irrespective of if the ethical or social implications of technology are considered, they will still be present – ignorance will not help the situation.

The value-sensitive design literature often frames VSD as a method striving toward "progress over perfection" (Friedman & Hendry, 2019). And since it is iterative, there are still opportunities to react, adjust, and modify the technology to produce a better outcome even if the first round is imperfect.

6.3.6 Responsibility

Responsibility is the attribution of certain actions to a person or entity. In general, it is the causal relationship between an agent and their actions: the agent is *responsible* for their actions. In this book, the focus is on moral responsibility (from here on, simply "responsibility"), which refers to the ethical aspects of actions, outcomes, and ways of being (Talbert, 2019). Here, agents are those that are *morally responsible* for their actions and the outcomes of their actions: these actions and outcomes are judged from an ethical perspective, that is, for rightness or wrongness. Moral agents generally include adult human beings, but not children, those without full mental capabilities (i.e. suffering from dementia), and non-human animals. The latter may be considered ethical subjects which deserve moral consideration but should not be held responsible for wrong behaviors since they do not understand the ethical dimensions of their actions.

Responsibility includes liability and blameworthiness, where one is held accountable for harmful outcomes (i.e. a consequentialist perspective) of actions, or the failure to act to prevent harm. Liability can refer to legal liability, where a person or legal entity (such as a company) is held responsible for outcomes of their actions, products, services, etc. Usually, responsibility is highly focused on wrongdoing, but it also includes positive aspects such as praiseworthiness (Van de Poel & Sand, 2021) . Here, morally desirable actions or outcomes are linked with their source, and that source may be commended. For example, if an engineer helped to develop a search and rescue drone that was used to save a life, that person could be praised for their contribution to this outcome. It should be noted that there is a difference between the level of responsibility an actor is obliged to fulfill (i.e. their duty, as in deontology), and the level of responsibility that the person or entity *chooses* to take on; it is possible to voluntarily take on more responsibility than required. For example, a virtuous engineer could decide to take on an increased level of ownership of both the positive and negative impacts of their industry, re-direct their work to right some of the wrongs, accept that sometimes their technology isn't always necessary, and try to enhance human flourishing by working with marginalized stakeholders.

There are many complexities in assessing responsibility in modern technological design. One such complexity is the problem of many hands (Van de Poel, 2015). The development of most technologies is complex and involves the collaboration of tens, hundreds, or thousands of individuals – the many hands. Therefore, tracing the unique contribution and responsibility of each person to a certain outcome can be challenging. In some industries, such as aerospace – where quality is highly critical – the approval of each step of a manufacturing process or design is often accompanied by approval by an individual, an engineer or quality assurance inspector for example. However, this documentation is rarely used to identify praiseworthy or blameworthy actions outside of the company; in fact, engineers and technical project managers are almost never held accountable on criminal charges. In 2018 and 2019, two Boeing 737 Max aircraft crashed killing 346 people. This resulted in massive fines and restitution for the victims' families, but no individuals at the company were criminally charged – despite Boeing being found to have lied to the Federal Aviation Authority (FAA in the United States) by the Department of Justice, and despite selling a safety-critical feature as an optional-extra (O'Kane, 2021). Perhaps engineers and managers at technology companies have been too protected from personal responsibility, especially when one considers the widespread impacts their work can have.

The Collingridge dilemma is another challenge in technological development:

> When a technology is still at an early stage of development, it is still possible to influence the direction of its development, but we do not know yet how it will affect society. Yet, when the technology has become societally embedded, we do know its implications, but it is very difficult to influence its development. The dilemma is one of the biggest challenges for responsible design and innovation.
>
> (Kudina & Verbeek, 2019)

The iterative nature of VSD helps to combat this dilemma with design changes taking place as the technology becomes more embedded into a social context. Another way forward is using pilot programs and robust testing together with communities using a citizen science approach (Davies & Horst, 2015).

6.4 Methodological Approach

In this section, several methodological approaches that are useful in the ethics of drone design are presented.[2]

6.4.1 World View

World view is the overall paradigm a researcher holds about the nature of reality. It is basic sets of beliefs that guide action, and a "general philosophical orientation about the world and the nature of research" (Guba, 1989). In a VSD process, where engineers may be collaborating with social scientists and ethicists, it is particularly important to understand, appreciate, and respect that one's collaborators may hold fundamentally different world views – and to utilize the strengths of each when appropriate.

There are three main world views that are utilized in scientific research:

- Positivism
  - There is one, objective reality
  - Value-free research
  - Researcher must be independent and objective
- Constructivism
  - Reality is interpreted differently by different people
  - Research cannot be value-free
  - Researcher must accept they are not fully objective

- Pragmatism
  - Puts focus on the research problem
  - Not committed to any one system of reality

Most engineers operate under the positivist world view. Positivism states that there is one reality "out there," which should be studied in a detached and objective manner. Research should be value-free, and the researcher must be independent and objective. Experimental methods are utilized, and data are often quantitative. In positivism, the research design is fixed (Gamborg, 2018), and views the researcher as being separate from the world they study (Guba, 1989). Therefore, human values (see "Human Values") and the values of the engineer or designer (see "Designer Values") should not have an impact on scientific research. A positivist world view is useful when undertaking the technological aspects of VSD – for example, in predicting the impact energy of a drone during a crash based on its kinetic energy, sharpness, and material properties.

In contrast, constructivism – often utilized by social scientists and humanists – places focus on the subjective experience of reality. It states that reality is interpreted differently by different people: that reality is socially *constructed* (Creswell & Creswell, 2017; Gamborg, 2018). Research cannot – and should not – be value-free, and the researcher must accept that they are not fully independent or objective. Non-experimental methods are utilized, and data are often qualitative. The research design is flexible, and the researcher is seen as an integral part of the world they study (Guba, 1989). Therefore, under a constructivist world view, researchers must be upfront about and accept that they are not fully objective, and that research cannot be value-free. This world view aligns with the value-oriented approach of VSD and is useful in the social aspects of VSD – for example, studying how people *perceive* the safety of different drone designs.

A third world view, pragmatism, is most concerned with the research problem itself and is agnostic to the perception of reality – it employs a plurality of approaches to derive knowledge about the problem (Creswell & Creswell, 2017). Pragmatist researchers look to "what and how to research based on the intended consequences" and are "not committed to any one system of philosophy and reality", meaning they can make use of multiple world views, assumptions, methods, and forms of data collection and analysis (Creswell & Creswell, 2017). Objective or subjective approaches are utilized depending on which best suits the research problem at hand. Pragmatism fits very well with VSD, as there can be benefits in working with a positivist world view when performing the technological analyses, while utilizing constructivism for the social and value-oriented aspects – such as the characterization of good drones and evil drones. A pragmatic world view was utilized in the development of the prototype drones in this book.

6.4.2 Research Approach

There are various research approaches that can be utilized in the ethics of drone design:

- Quantitative
  - Results expressed in numbers
- Qualitative
  - Results expressed in words
- Mixed methods
  - Combination of numbers and words

A quantitative research approach lends itself well to many engineering studies; it is deductive in nature with the resulting data expressed in numbers (Creswell & Creswell, 2017).

Qualitative research approaches lend themselves to social or human problems and are often utilized – along with mixed methods – within the social sciences and humanities (Creswell & Creswell, 2017). These forms of inquiry can be inductive, require a level of interpretation of data by the researchers, and result in data expressed in words.

Mixed methods research includes both quantitative and qualitative data.

> Mixed methods research is an approach to inquiry that combines or associates both qualitative and quantitative forms. It involves philosophical assumptions, the use of qualitative and quantitative approaches, and the mixing of both approaches in a study. Thus, it is more than simply collecting and analyzing both kinds of data; it also involves the use of both approaches in tandem so that the overall strength of a study is greater than either qualitative or quantitative research.
>
> (Creswell & Creswell, 2017)

VSD combines engineering, social science, and ethics; therefore, a mixed methods research approach – which allows the use of both qualitative and quantitative means as well as data in the form of numbers and words – is often useful. A mixed methods approach was used in developing the prototype drones in this book.

6.4.3 Research Design

There are three types of research design often employed in scientific inquiry: deduction, induction, and abduction (Creswell, 2014). Deduction involves applying a general rule or theory *to* a particular case. Induction involves creating a rule or theory *from* particular cases. By contrast, in abduction, cases inform theory and theory shapes cases in a concurrent or iterative way. The three types of research design can be summarized as:

- Deduction
  - Applying a general rule or theory *to* a particular case
- Induction
  - Creating a rule or theory *from* particular cases
- Abduction
  - Cases inform theory and theory shapes cases in a concurrent or iterative way

Abduction is a good fit for VSD as it too is based on an iterative and concurrent development approach. Abduction has the drawback of being complex and less firmly grounded; for example, in deduction the theory is assumed to be correct and not be questioned during the research process. On the other hand, abduction allows flexibility and the opportunity to adjust theory as new information comes in. Abduction requires that the researcher embrace a certain amount of uncertainty (Sollie, 2007) and a level of ignorance which has been suggested in the technology ethics literature as important in the development of new technology (Van de Poel, 2016). The abductive research design was used to develop the prototype drones in this book – for example, the Danish healthcare drone was developed in parallel with the ethical framework for drones in public healthcare.

6.5 Ethical Frameworks

Ethical frameworks are applied ethics tools which suggest structured approaches to an ethical situation. Many ethical frameworks have been developed for new technologies, including one for the evaluation of experimental technology (Van de Poel, 2016), for the responsible development of AI (Floridi et al., 2018), for care robots (see care-centered VSD such as Van Wynsberghe (2016)), and for drones in public healthcare (Cawthorne & Robbins-Van Wynsberghe, 2019, 2020). A benefit of ethical frameworks is that they provide a starting point for ethical analysis without being overly narrow or prescriptive – a risk in the use of ethics checklists, for example ("Ethics Issues Table – Checklist," 2014; Kiran, Oudshoorn, & Verbeek, 2015). A downside is that they are more complex to apply than a checklist, and might omit, under, or overemphasize certain aspects of the ethical analysis. Ideally, the framework should be able to take contextual issues into consideration, or be developed within the context of use.

The ethical framework for drones in public healthcare, which was used to develop the prototype Danish healthcare drone, is shown in Figure 6.1. The ethical framework influenced the technological choices in a multitude of ways, as well as acting as documentation of the values designed for and the way in which some of the value conflicts were addressed. For more details, see Chapter 2, "The Healthcare Drone".

The ethical framework includes the two highest levels, which cover the ethical phase in this book. They are made up of ethical principles at the highest level and human values at the level below. The ethical principles are beneficence, non-maleficence, human autonomy, justice, and explicability. The human values include human welfare, jobs/human skills, privacy, safety, security, calmness, environmental sustainability, etc. The two lower levels of the framework include the social phase, and below that, the

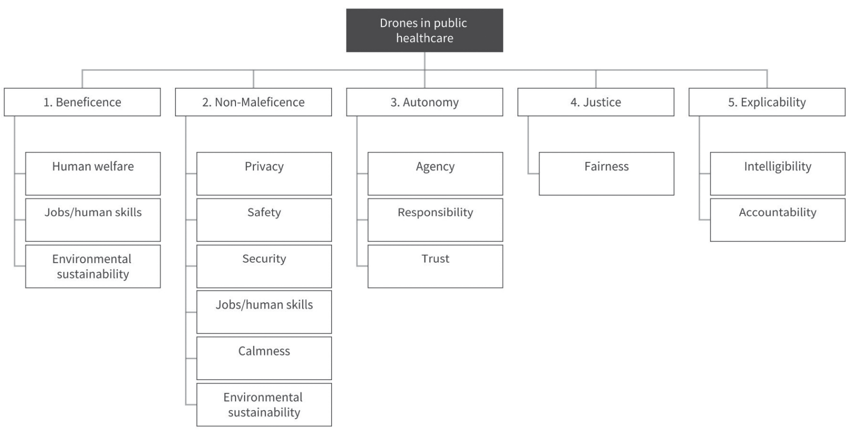

Figure 6.1 An ethical framework for designing healthcare drones. This is the top of the framework, which contains ethical principles and human values – the ethical phase of VSD. Not pictured, but below this level are contextual considerations – the social phase, and at the lowest level are design requirements – the technological phase. Using the framework makes the connections between the technological capabilities, the context, and the resulting ethical implications explicit. Some ethical considerations are suggested by the framework, but these assumptions should be applied with caution since they may not fit in every case – an abductive research approach is recommended (see "Research Design").

Source: Image by the author, based on Cawthorne and Robbins-Van Wynsberghe (2020).

technological phase. The social phase includes contextual considerations and empirical work, and the technological phase entails defining design requirements. The social and the technological levels of the framework are not shown and must be completed by the engineer and collaborators based on the particular context of use and technological approach. Ultimately, the design requirements – in view of the social phase and the ethical phase – should support the ethical principles and human values and thereby, human flourishing.

6.6 Ethics Standards, Certifications, and Labels

In recent years, there has been an increased focus on the ethical and social impacts of technology, and on the need to consider these factors in the design phase. One result has been the development of tools including ethics standards, certifications, and labels aimed at helping engineers and companies that develop technology to consider ethics in a systematic way – and to be able to certify or label their products as such.

The Institute of Electrical and Electronics Engineers (IEEE) is the world's largest professional association, and perhaps the most important for drone engineers. The IEEE has a human-centered mission statement: "to advance technology for the benefit of humanity". A key activity of the IEEE is creating standards, and in 2021 they released a new 7000-series of ethics standards: the IEEE 7000-2021 Standard Model Process for Addressing Ethical Concerns during System Design (IEEE, 2021). The standard is built on a foundation of value-based engineering (i.e. human values, value-sensitive design) aligned with the approach taken in this book. Other standards in the series – which address topics including explicability, privacy, and human welfare – are listed below; the standards cost around €100 each.

- 7001-2021 Standard for Transparency of Autonomous Systems (the value of explicability)
- 7002-2022 Standard for Data Privacy Process (the value of privacy)
- 7005-2021 Standard for Transparent Employer Data Governance (the value of explicability)
- 7007-2021 Ontological Standard for Ethically Driven Robotics and Automation Systems (human values in general)
- 7010-2020 Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being (the value of human welfare)

After developing a product – ideally using an ethically informed process – companies can apply for ethics certification. The IEEE offers an

Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS) ("The Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS)", 2023). The certification focuses on intelligibility and accountability (i.e. explicability), and reduction in algorithmic bias. The objective of this certificate and associated markings is to allow customers to quickly and easily identify products that have been deemed "safe" and "trusted". There is also the CertifAIEd Mark for AI systems ("IEEE CertifAIEdTM – a certification program for assessing the ethics of Autonomous Intelligent Systems (AIS) ", 2022) which focuses on intelligibility and accountability (i.e. explicability), reduction in algorithmic bias, and privacy. The Foundation for Responsible Robotics, a nonprofit organization based in the Netherlands, is developing an Ethical Quality Mark for (AI Based) Robotics where an independent, external group of experts in responsible robotics assesses the system via human-value based criteria including security, safety, privacy, fairness, sustainability, accountability, and intelligibility ("Quality Mark for (AI Based) Robotics," 2023).

In some cases, there are no or few legal requirements when new technologies are first developed. Companies may choose to voluntarily follow standards, apply for certifications or quality mark, and/or practice self-regulation, all of which can provide guidance in new and uncharted territory until the legal system catches up. Some approaches to self-regulation include value sensitive design, ethical frameworks, privacy-by-design (PbD), and capability caution, which is explained next.

6.7 Capability Caution

Capability caution is the setting of well-reasoned limits to the technology's capabilities during the design phase (Cawthorne & Devos, 2020). In drone design, it means defining upper limits to the drone's capabilities. This simplifies the technology, reduces scope-creep, and reduces the risk and severity of misuse. Capability caution was used extensively – and the approach was developed abductively – during the design of the Danish healthcare drone (see "The Healthcare Drone"). Capability caution is in contrast with the typical capability maximization (or "optimization") engineers undertake (Van de Poel, 2009). A capability maximization approach would aim to make a drone that flies as far and fast as possible, collecting the most data possible; a capability caution approach would strive for a drone that has the necessary range for the given use-case, at the necessary speed, and which minimizes data collection to that only strictly necessary. Capability caution in drone design includes five design principles which ask the engineer to the consider context of use, privacy, jobs and human skills, safety, security, misuse, and the future (Table 6.2).

Table 6.2 Five capability caution design principles for drones

Design principle	*Approach*	*Questions to consider*
Context of use	Focused design for a specific context versus "one-size-fits-all" Focused use plan Minimize functionality outside specified context and use plan Address dual-use issues	How can the drone be designed for a specific context? What is the drone's use plan? How can dual-use risks be minimized?
Privacy	Follow the privacy-by-design (PbD) principles Adhere to the General Data Protection Regulations (GDPR) Choose sensors that preserve privacy Minimize the drone's ability to spy/stealth	How can the drone's design ensure privacy is preserved? Is more data being collected than strictly needed? Is the drone highly visible and audible?
Jobs and human skills	Consider the level of the drone's automation VS remote operation or telepresence Decide what work should be automated and what work should be done by humans Carefully consider and manage the impact to the existing workforce; collaborate with them	How can the drone be designed to create meaningful human work? How can the drone's design minimize negative impacts on the workforce?
Safety, security, and misuse	Carefully define upper limits to the drone's capabilities including its payload, range, weight, speed, and operational boundaries Maximize the difficulty of using the drone to carry unapproved cargo including bombs or drugs Limit the drone's ability to be crashed into crewed aircraft, people, and critical infrastructure	How can the drone's ability to carry dangerous or illegal cargo be minimized? How can the design limit the likelihood and severity of negative outcomes should it fall into the wrong hands or is highjacked?
The future	Avoid that the drone's design will lead to undesirable drones in the future Consider the future consequences if this drone becomes ubiquitous Clearly define the upper limits of the required functionality	What will be the long-term impacts of developing this drone, and drones of this type? What if this drone is everywhere? Has the drone been over-specified? Should this drone be developed at all?

Source: Cawthorne & Devos (2020).

These design principles were developed through insights from value-sensitive design, philosophy of technology, and empirical evidence of existing and emergent impacts of drones on society – thus they have a lot of overlap with topics covered elsewhere in this book. The design principles were developed to give drone engineers design prompts that could easily be applied, but without being overly prescriptive, which is why they take the form of approaches and questions to consider during the design process.

6.8 Multiple Futures

Sometimes, it can feel as if technology is a force of nature – it moves with seemingly unstoppable power. The idea that technology moves unrelentingly, and only toward a single future, is called technological determinism (Winner, 2017). Even engineers and scientists can feel that they are not in control of the forces at play, that they must either get onboard or move aside. However, most philosophers of technology no longer subscribe to a deterministic perspective, which has since been replaced by that of multiple futures. Multiple futures highlights that the future is not pre-determined (or even determinable), and that there are multiple courses that the future may take. Speculative design (Dunne & Raby, 2013) makes use of multiple futures (see "Speculative Design"), and the book *Designs for the Pluriverse* (Escobar, 2018) helped to further popularize the paradigm. In one model, called the 4P model – shown in Figure 6.2 – four futures are considered: the most likely or probable, the plausible, the less likely but still possible, and the *preferable*. Note that the preferable future might not be the most likely. Therefore, changes must be made at the present time to actively steer toward this more desirable future. Value sensitive design and speculative design are two ways to steer technology toward a preferable future.

There are many forces which tend to push technological development in certain directions, the most powerful probably being economics and the profit motive. Other motives include competition and nationalism; take for example the development of the space shuttle by the United States during the cold war era competition with Russia. In 1962, John F. Kennedy made a famous speech proclaiming that the United States would go to the moon and achieve other goals "not because they are easy, but because they are hard" ("We choose to go to the Moon," 2023). In under 10 years, the objective had been achieved, but this rapid acceleration of spacecraft development did not happen for deterministic reasons – it required massive investments in NASA's budget, scores of engineers, high-tech materials, and tons of rocket fuel.

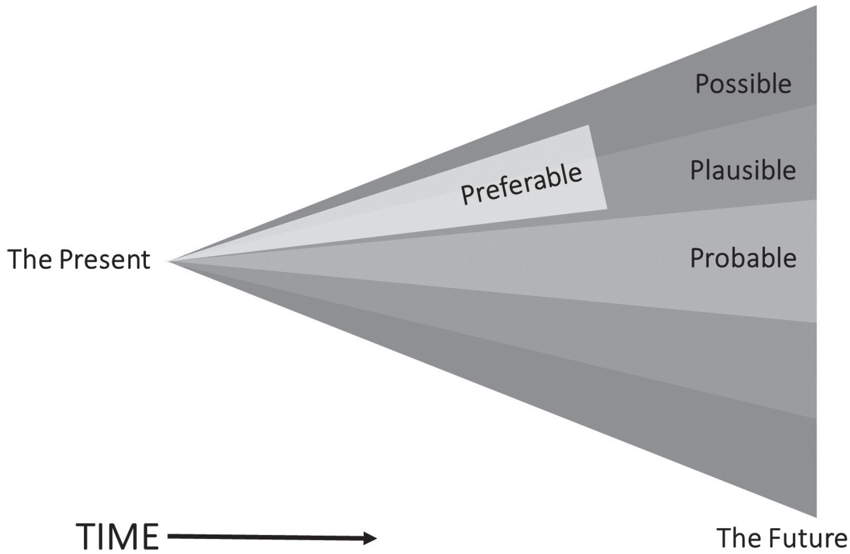

Figure 6.2 The 4P model showing probable, plausible, possible, and preferable futures. Time is shown on the horizontal axis, with the present on the left and the future on the right. The various paths represent different ways to develop technology, and suggest that the preferable direction is not always the future that is most probable. Value sensitive design and speculative design are two ways to alter this trajectory toward a better future.

Source: Graphic by the author, based on Dunne and Raby (2013).

6.9 Speculative Design

Speculative design is a methodology where imagined (i.e. speculative) futures or scenarios are created, and products/services/artifacts are designed that uphold the functions and values that fit into the scenario (Dunne & Raby, 2013). One example is vehicle designs for an imagined future where the United Kingdom splits into different socio-political micro-kingdoms (Dunne & Raby, 2023). The Digitarians are conservative authoritarians, and embrace technology and its implicit totalitarianism. Their vehicle – the Digicar – is a boxy electric pod which is connected, tracked, and monitored for the purposes of maximum efficiency. The vehicles designed for the Bioliberals – social democrats that embrace biotech – are called Biocars. These vehicles are small, lightweight, and slow-moving, resembling four-wheel bicycles fueled by biogas.

The wooden frame of the search and rescue drone (see the chapter "The Search and Rescue Drone") was developed using the speculative design methodology; a preferable future was defined, and then the drone's frame was designed for this future (Cawthorne & Iversen, 2021):

> In this preferable future, environmental sustainability, human health, and meaningful work are highly prioritized. The speed of technological "progress" is slowed to a more controllable pace, and there is emphasis on the use of local resources rather than on the global supply chain. Environmentally unsustainable practices and the use of non-renewable resources such as those based on petroleum are discarded; natural and renewable resources such as trees are grown in vast numbers and utilized locally. Unsafe working conditions are not accepted by the workers themselves, labor unions, and the public at large–both at home and abroad. Technology is developed cautiously and in close collaboration with multiple stakeholders, and care is taken that the new technology does not create unnecessary problems. Engineers, designers, and factory workers enjoy and take pride in their work, and the results of their efforts are utilized locally giving them insight into the impact they have on their community. A large portion of the workforce is in the manufacturing sector which produces the goods needed by the community, and skills and expertise in craft trades are as highly respected as those of knowledge workers.

The spiritual drone (see the chapter "The Spiritual Drone") is another, more extreme example of speculative design – a design for a world of spirituality and giving rather than one of commerce and data collection, where environmental sustainability and transparency of operation are taken to heart.

6.10 Art

Art is the activity of producing works that can evoke emotion, explore conceptual ideas, and/or demonstrate technical skills. Art includes works of painting, sculpture, architecture, theater, dance, literature, poetry, music, film, and recent additions including interactive media. Artworks can be representational (looking like something, such as person), formal (evoking a form or shape), and/or expressive (evoking meaning or emotions) (Adajian, 2018). Artworks may be characterized as being aesthetic and non-functional, but the line is blurry with many useful "designer" objects being beautiful, and some artworks being highly functional.

Some define an artist in commercial terms: an artist is someone who has sold their creative works; yet there are famous examples of accomplished artist that sold very little work during their lives such as van Gogh ("How Many Paintings Did Vincent Sell during His Lifetime?," 2023). Additionally, many commercial artists only make art part-time and have other jobs. Who may call themselves an artist may become important, especially if the actions of the artist or themes in an artwork are considered provocative. Take for example the exhibition in Poland of contentious works purportedly critiquing "cancel culture" (Gera, 2021). Are these the works of true artists, or of racists being passed off as art?

Making art and being an artist is not a free pass to do anything one wishes, and there are special ethical considerations in this context. Berleant (1977) suggests the ethics of art be framed on two distinct but related axes: the art object itself and the artist. There are three types of ethical demands on an artist: those that apply to everyone as moral beings, those that apply to artists as social participants with some control and influence, and those that apply specifically to artists due to characteristics of their particular tasks. It is argued that artists acquire an additional responsibility: a responsibility to art itself, to the integrity of their artistic vision. Within these constraints, however, artistic freedom "has a special force" – "over the integrity of an artist's vision no screen should be placed". In this way, being an artist is similar to being an engineer – with increased power comes increased moral responsibilities.

Artistic practice can cultivate craft skills, and getting "out of one's head and into one's hands", that is, *thinking* by *doing*. Engineering and technical skills can be highly useful in making art, as in *Space Program* by Tom Sachs (Sachs, 2007). The fictional space program involves the mining an asteroid for "rare earth" metals and includes a functional rover, full-sized lander, live video feeds, and blow torches for rocket engines (Sachs, 2007). Here, the materials and methods typically employed for instrumental ends in engineering are repurposed to make objects that support "sympathetic magic" (Sachs, 2018).

Art can be a great way to explore, critique, and even subvert drones and other technologies. *The Drone Survival Guide* by Ruben Pater helps the user identify armed and reconnaissance drones from their silhouettes (Pater, 2013), and the *Drone Shadow* series by James Bridle shows the life-sized outlines of predator drones painted onto city streets or museum floors (Bridle, 2012).

Unlike normal engineering practice, art allows one to play with contradictions, be subversive, and break things – in a relatively safe space. One example is the non-objects made by Anish Kapoor (Kapoor, 2023).

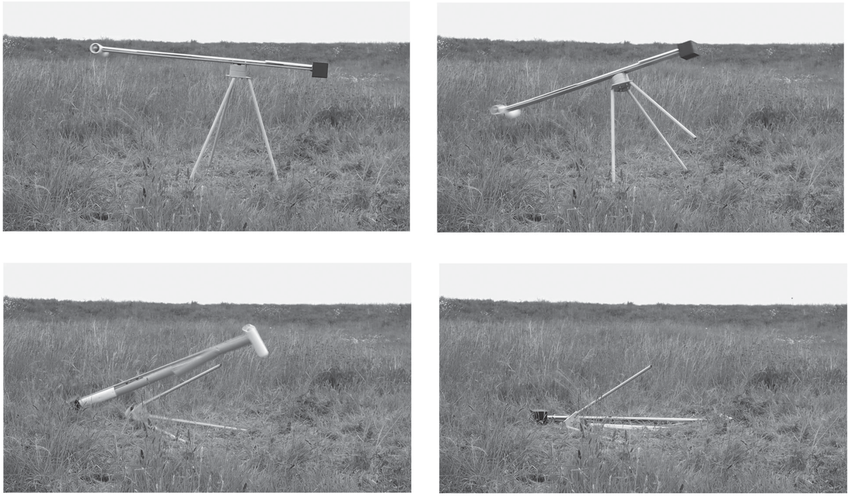

Figure 6.3 Sequence (from top left to bottom right) of the only performance of the kinetic sculpture *Homage to Technology* as the sculpture spun itself to destruction.

Source: Artwork and images by the author.

By definition, an object cannot be a non-object, but Kapoor investigates the inherent contradiction with compelling conclusions. This approach of essentialism (thinking about what makes something what it is) was instrumental in the development of the spiritual drone: what makes a drone a drone, and when does it stop being a drone?

Art is a way to try out radical ideas – even those that would be dangerous or irresponsible in a product on the market. *Homage to Technology* – shown in Figure 6.3 – is a self-destructive kinetic sculpture made by the author. The ephemeral work calls into question our potentially catastrophic obsession with technology.[3] The title references the 1960 artwork *Homage to New York* by Jean Tinguely, an expansive, complex, noisy, and ultimately self-destructive sculpture ("Homage to New York: A Self-Constructing and Self-Destroying Work of Art Conceived and Built by Jean Tinguel (1960)," 2023). During its only performance, *Homage to Technology* was placed outdoors in a natural setting and set into motion, spinning around its central axis at increasing speeds until ultimately self-destructing. The work hints at technology's seemingly runaway nature, its increasing violence, and potential impermanence – the result of a system out of control.

Homage to Technology specifications:

- Width = 2.5 m
- Depth = 1.0 m
- Height = 1.5 m
- Weight = 30 kg
- Motor maximum power = 2,400 watts
- DC Voltage = 24 volts
- Maximum DC Current = 100 amps
- Electric jet engine turbine maximum rotational speed = 30,000 RPM

This work (along with The Spiritual Drone) was accepted into the Georgia Tech (United States) Robotics X Art exhibition, and photos and video of its performance are on permanent display in the online gallery ("Robotics X Arts Exhibition: Opportunities and Issues in Robotics Applied in the Arts," 2021) .

In this section, art has been framed in an instrumental, results-oriented way: as a methodology to achieve some aim. However, perhaps one of the great features of art is that it can do away with all semblances of practicality – art does not *need* to fulfill any functional requirements as engineering does (Herath & Kroos, 2016). Some artists approach their work in an overtly *anti*-method process; take, for example, Jonathan Meese (Meese, 2023). Messe claims to be the servant of art, which means "no inspiration, no creativity, and no idea. You just do something". The anti-method approach can be an especially useful exercise for academics and engineers who are trained to be methodical in their work – they can be reminded that there are alternatives: feelings rather than thoughts, practice, and experience rather than theory, the body rather than the mind. Hopefully, we do not corrupt art by approaching it in such a practical way.

Notes

1 This section relies heavily on the work of Friedman and Hendry, along with their collaborators (Friedman & Hendry, 2002; Friedman & Hendry, 2019; Friedman et al., 2013).

2 This section builds upon the methods section in my PhD thesis (Cawthorne, 2020).

3 This artwork was self-funded by the author, and was built from second-hand electronics and metal from the university's scrap bin.

7 The Future

What type of world do we want to live in? What direction should technology take? What should our relationship with technology be? To enhance us, make us super-human cyborgs? To disappear into the background, so we can focus on our human-ness, to spend time interacting directly with other people and with nature? One where drones are present? One where drones are not present? Or one where drones are only present in certain ways and under certain circumstances?

Thinking about the future involves imagination, speculation, and creativity. A number of methods have been presented which aim to cultivate these skills, including speculative design and art (see "Speculative Design and Art"). Various forms of art, including visual art like that in Figure 7.1, science fiction books, films, and series, can inspire critical reflections about future technologies and their potential impacts. For example, the television series *Black Mirror* presents cautionary tales of near-futures where drone bees used for pollination are weaponized, where killer dog-like robots hunt humans, and where a deceased loved-one can be simulated by an AI-trained robot ("Black Mirror," 2023). More utopian visions are portrayed as well, for example in some aspects of the various *Star Trek* series. Hopefully this book has shown that both the utopian "good drone" narrative, as well as that of the dystopian "evil drone" are too simple, and that the most likely future is one that will require a nuanced approach to the ethics of drone design.

7.1 Recommendations

Hopefully, this book has provided good arguments that drones have ethical importance, design has ethical importance, and value-sensitive design is a way to create better technologies. In this chapter, specific recommendations are made for various stakeholders which aim to move drone design toward a more ethically oriented approach.

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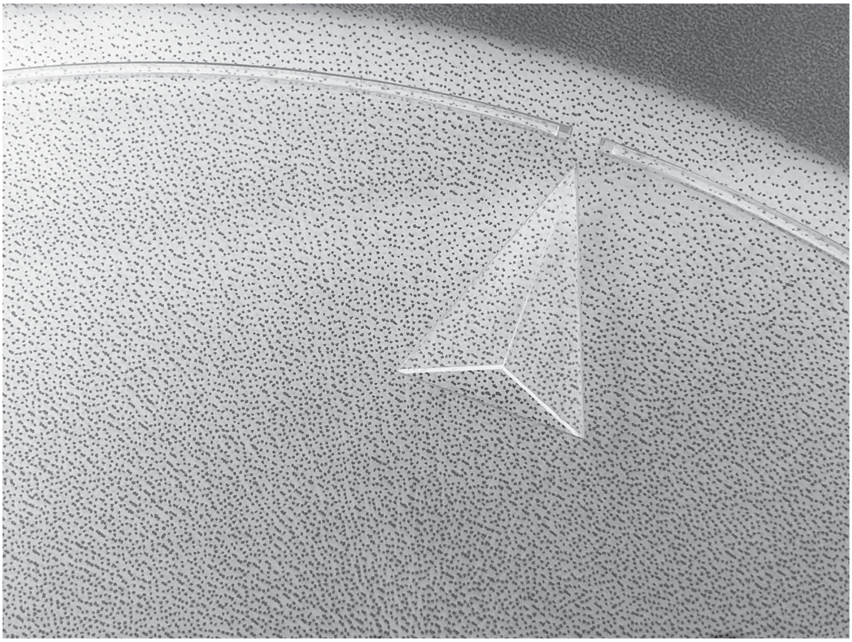

Figure 7.1 Detail of “I am only here for your gold”.

Source: Artwork and image by Samuel Swope, used with permission.

7.1.1 Organizational

The organization of many educational institutions and companies do not lend themselves to the consideration of ethics in technology – including in drone design. At universities, most research takes place in relative isolation where specialists in engineering, social science, and ethics each focus on their own piece of a very complex puzzle, researching and writing only for their immediate peers – and are rewarded for doing so. Technology companies and governmental and non-governmental funding bodies are usually focused on either profit maximization and/or instrumental uses of technology with limited understanding or consideration of its broader social and ethical impacts. If this were not the case, the need for engineers and designers to practice VSD would be reduced: there would be social scientists studying the interactions between technology and society and ethicists working on the emergent moral aspects of new technologies, with each specialty feeding engineers and each other with inputs. Unfortunately, in general this is not the case. VSD is one way to address these issues, but a more fundamental shift in organizational structures would address some of the root-causes.

This shift could include multidisciplinary, problem-focused teams addressing important, existential, and "wicked" problems such as global hunger, climate change, and peace. This holistic and pragmatic approach (see "World View") would put the problems facing humanity and the environment at the forefront and deemphasize hyper-specialization, instead calling for the application of appropriate expertise to multiple aspects of the problem. For example, climate change cannot only be address technologically, it will require the integration of research from natural science and engineering together with an understanding of social aspects of resource consumption and ethical analysis of the good life, our relationship with the natural environment, and our duty to future generations.

There are many specific challenges in using VSD to develop drones in the real world, so in 2019 and 2020 an action research study was conducted at the author's research group at the University of Southern Denmark (Andersen & Cawthorne, 2021) . The study identified four types of barriers to the adoption of VSD: paradigmatic, strategic, structural, and cultural (see Table 7.1). The study then proposed various actions and recommendations to address these barriers, with a focus on actions that "champions" of VSD (advocates of the methodology) could take to address these challenges. These four types of barriers are deeply engrained into engineering culture and systems of reward and will not be easily changed. But identifying them early allows the course to be altered and hopefully aligned with a more preferable path.

As well, the study addressed different types of focus and methods of delivery in moving toward a value sensitive approach (see Table 7.2). These could use existing structures as well as new structures, with narrow (discipline-specific), intermediate (semi-discipline specific), or broad (interdisciplinary) scopes. The barriers to VSD should not be underestimated; since this study, overall adoption within the author's university has been slow, and large drone research projects have not been able to utilize it successfully. However, some engineering students have embraced a VSD approach, including ethical considerations into their robot and drone designs in existing interdisciplinary courses, and written theses using VSD. The author created an elective course, *Ethics in Drone, Robotic, and Software Systems Design*, which – after a slow start – has begun to attract a reasonable following of students. The key seems to be perseverance: these changes take time – so the VSD mantra of "progress over perfection" should be kept in mind.

Table 7.1 Some barriers to implementing value sensitive design, specific challenges, "champion" actions (champions are "sponsors" which support VSD), and recommendations which can be used to overcome these barriers

	Challenges	*Champion actions*	*Recommendations*
Paradigmatic barriers	Value-neutral or value-free paradigm in engineering Issues of engineers' responsibility Engineers as "weak" (with limited control)	Address the existing paradigm Accept more responsibility for one's work Show how technologies embody values	Select and make explicit the chosen research paradigm Lead by example Use VSD
Strategic barriers	VSD being overshadowed by similar efforts such as the United Nations Sustainable Development Goals (UN SGDs)	Embrace similar efforts; demonstrate how VSD can address "wicked problems" such as those addressed by the SDGs	Support initiatives that are similar to VSD, while asserting the unique features of each
Structural barriers	Lack of funding and recognition for interdisciplinary collaboration Economics and market forces limiting implementation	Influence funding bodies to prioritize interdisciplinary work/"wicked problems" Demonstrate VSD's potential, long-term economic benefits, and the resulting unique technologies	Increase funding for interdisciplinary collaboration More incentives for including ethics in technological design, and more punishments for transgressions
Cultural barriers	Cultural beliefs about limits to engineers' agency The belief that engineers do not have power over the use of technology or its political or human impacts A focus on technology over humans or nature	Encourage and practice reflection about the limits and extents of engineers' agency Utilize participatory and deliberative approaches in technological development Expose themselves and peers to other cultures, paradigms, and fields via interdisciplinary collaboration	Utilize both top-down (mission statements) and bottom-up (workshops facilitated by champions) approaches to slowly shift to a value-oriented engineering culture Embrace participatory methods Learn from other cultures, paradigms, fields via interdisciplinary collaboration

Source: Andersen and Cawthorne (2021).

Table 7.2 Some ways to move university research and engineering education toward a VSD approach

	Delivery via existing structures	*Delivery via new structures*
Narrow focus (discipline-specific)	Offer an elective course in VSD Integrate VSD into research projects Exercise capability caution – decide what drones *not* to develop Develop methods for VSD in engineering education Require a course in VSD and engineering ethics	Establish a series of workshops for students to engage with VSD, ethics, and sustainable development in an interdisciplinary way Establish a series of workshops for the technical faculty to engage with these topics Create mechanisms for participatory design where engineers work directly with stakeholders
Intermediate focus (semi-discipline specific)	Create an alliance for ethics in engineering open to experienced researchers, teachers, and engineering students	
Broad focus (interdisciplinary)	Expand existing interdisciplinary research, in dustry collaboration, and teaching activities (i.e. with social scientists, ethicists) Position the university as a leader in ethically informed and holistic technology development Influence funding bodies to require consideration of ethics and social impacts in technological research projects	Create a new multidisciplinary research center for VSD and ethics in engineering

Source: Andersen and Cawthorne (2021).

7.1.2 *For Drone Engineers*

This book is aimed at drone engineers, and as such there are extensive recommendations for these readers. First, there are a multitude of contemporary engineering projects that should be questioned from a value-sensitive perspective; to name just a few:

- Drone mechanical engineering where lightweight structures are prioritized over all else, including human health and environmental sustainability
- Drone electronics where maximum technological performance is prioritized over high environmental impact and low fairness for workers
- Drone software which aims to maximize drone autonomy, cutting humans out of the loop and supporting office jobs rather than hands-on work
- Drone sensors which collect as much data as possible, rather than privacy-by-design or capability caution
- Drone AI, where unintelligible, "black box" systems are okay as long as they "work"

These current paradigms are often supported by the economic systems that reward minimization of human labor (costs) and neglect externalities such as environmental impact.

One way to improve upon this situation and address the unpredictable nature of technological development is using a virtue ethics approach (see "The Ethical Phase Methods") in order to become a "good drone engineer". The "good drone engineer" is one that pursues the techno-moral virtues and makes drones which facilitate the spreading of positive virtues (Vallor, 2016). They practice humility by collaborating with experts in other fields to get a holistic understanding of the problem first before looking for a "solution" and are cautious of applying purely technological solutions to social problems (i.e. technological solutionism). They are fair and *choose* to take more responsibility for the technology they develop than they are *required* to take (see "Responsibility"). They exhibit courage by pushing back against those that would develop and use drones in bad ways. And they exhibit moral wisdom so that their moral progress keeps pace with their technological progress (Van den Hoven et al., 2012).

The specific industry and project that an engineer chooses to work on has a significant impact upon meta-ethical considerations. Although the technical work may be somewhat similar, building low-cost educational technologies ("The Sierra Leone Educational Drone") has much different implications than developing a drone to deliver coffee in Australia ("Bonython Against Drones," 2023) or to shame people in traffic in Mexico City (Reilly, 2016). Making technologies for peace has much different ramifications than making technologies for war (dual-use).

Some describe the good engineer and those that practice VSD as activist engineers. They "create a new paradigm of engineering in which the engineer is equipped with not only technical tools and knowhow, but also with the requisite socioecological perspectives, knowhow and ethics" (Karwat, Eagle, Wooldridge, & Princen, 2015). Activist engineers may work with less powerful stakeholders, develop technologies that draw attention to unjust activities or environmental degradation, or create technologies of peace; a self-reflection guide for activist engineers is here (Karwat, 2020).

Which drones should good drone engineers develop then? This book showed three practical prototype drones and one artwork that were developed in a sincere attempt to make an unequivocally good drone. However, in each practical drone case, the answer to "should this drone be built?" was at best a cautious "maybe". Hopefully, these cases demonstrated how contextual drone design is, and how nuanced the consideration of technological specifications must be to make – maybe not a good drone, but a better drone. The cases also hopefully demonstrated that it is not just the outcome of the design process, but the way in which the process is conducted (i.e. procedural justice) that matters – who is taken into consideration, and the definition of success criteria (i.e. maximize payload or maximize safety).

The book *The Good Drone: How Social Movements Democratize Surveillance* (Choi-Fitzpatrick, 2020) details a number of drone *uses* that may be beneficial – estimating the size of demonstration crowds, documenting human rights abuses, and advancing climate change research. Sometimes, the drone need not do more than capture video to have an impact: drone footage of violence such as at protests, human-made disasters such as oil spills or nuclear accidents, and humanitarian crises such as migrants and refugees drowning in the Mediterranean Sea can raise awareness of these issues and lead to changes in public opinion and in policy. But it is difficult to generalize, and a main point of this book is that context, ethics, stakeholders, power, politics, and a multitude of other considerations go into the design of good drones.

7.1.3 For Drone Companies

There are a number of barriers to adopting an ethically informed design methodology in companies. The most obvious is the profit motive – companies exist in order to make money, and publicly traded companies exist in order to make money for their shareholders. Often, there will be conflicts between doing the right thing and doing the most profitable thing. There are innumerable examples of these conflicts; one is that between data privacy of users and the value companies can generate by selling that data. To a certain extent, we cannot blame the individual companies for this approach – it is the economic system that rewards such behaviors.

In order to make a significant change and to develop technology for the benefit of society, this economic system must be modified or replaced. Some attempts to do so include adding the cost of "externalities" into the price of production, such as with a carbon tax, which attempts to reduce CO_2 emissions. Capitalism succeeds at producing extremely low-cost goods, allowing the poor and middle class an elevated level of material wealth. But it does a poor job at protecting workers and the environment. Technology is often developed in ways that take advantage of the public's lack of knowledge and takes advantage of legal gaps in order to make a profit. Social media apps conceal their true business model – selling their customer's data – by providing a seemingly free service. Electric scooter companies take advantage of a lack of explicit legislation preventing them, and park their products on public sidewalks in cities all around the world. Universities have commercial considerations as well, making research groups a type of (often publicly funded) drone company. Some researchers may view themselves as public servants whose aim is to develop technology for the benefit of society, but they still have financial interests at stake including seeking outside funding and collaborating with companies.

Still, it is possible that an ethically informed approach to drone design could succeed in the marketplace since it could be embraced more readily by the multiple stakeholders engaged in the development process. In addition, when the criterion for success is maximum profit, most companies' approaches will look similar; a fundamentally different approach might be a way to differentiate oneself from competitors and create a totally unique product. For example, using a cartoon representation of a person in an airport body scanner protects the privacy and dignity of both those being scanned, as well as of the airport employees that must view the data (Spiekermann, 2015). A capability caution approach (see "Capability Caution") could lead to a simpler product, reducing development costs and increasing safety – and profits.

7.1.4 For Social Scientists

The social, the technological, and the ethical phases of VSD interact in interesting and sometimes unpredictable ways, and engineers need insights into context, culture, and human behaviors which social scientists can provide to make good drones. Social scientists should remember that technology is not just a given – that it can be actively shaped – and they should be proactive and involved in technological development to help shape it in a better way. They should also remember that most engineers have a positivist world view, and be prepared for the different perspective and methods engineers use (see "Methodological Approach"). Social scientists can help connect technologists with society, help to empirically identify new/relevant human values (i.e. through value coding of qualitative data (Friedman & Hendry, 2019), and expose engineers to other literature, methods of research, and even world views. It would be great if more social scientists were to reach out and help technologists to co-develop human-centric technologies.

7.1.5 For Ethicists

Ethicists should also be proactive in seeking out collaborations with engineers. Technological development is happening rapidly, and without a VSD approach and inputs from ethicists, it will likely continue on the path it is already on. New moral risks and opportunities are being realized all the time, and the ethicist is uniquely qualified to help frame, analyze, and advise on these topics. Ethicists can help to identify and prevent the naturalistic fallacy, a risk in stakeholder-centric approaches such as VSD. One approach is "the ethicists in the lab": where the (applied) ethicist is a key part of the research and development team and cohabitates the lab (Van Wynsberghe & Robbins, 2014). Ethicists can also combat the risk of ethics-washing, an emergent risk should ethics take a larger role in technological development in the future (Bietti, 2020).

7.1.6 For Lawmakers

Lawmakers should plan for and be prepared for technological disruption. Governments and policymakers should reward responsible practices such as self-regulation in industries – including the drone industry – and restrict irresponsible practices while always keeping the welfare of the public as their top priority. Lawmakers have a responsibility to ensure the economic and material welfare of the citizens, but human values should be prioritized and rewarded in the economic system. Fundamental changes need to take place such that environmental degradation is included in the cost of production, that workers are fairly compensated for their labor, and the coming impacts of drones and other forms of automation are prepared for. A fair distribution of the benefits and harms of drones should be devised, and protections from these changes – such as re-training and education – developed.

7.1.7 For Citizens

Citizens should be well-informed and proactive members of society. The average person can keep themselves up to date about what is going on around them – internationally, nationally, and locally – by reading the news (while keeping in mind that the news tends to be negative which may distort our thinking (Perlmutter, 2019)). They should orient themselves with a basic understanding of technology and be involved in giving input to technology developers, governments, etc. Value-sensitive design methods require significant input from the public as important stakeholders; if adopted, more citizens will be asked to participate in surveys, interviews, or focus groups. In this way, citizens can be proactively involved in the development of technology – even becoming citizen scientists. However, as is often the case, there will be instances where technologies are being produced that citizens object to; then, they should take it upon themselves to voice their concerns and to resist the technology.

7.2 Conclusion

This book presented a holistic approach to the design and use of drones through four case studies: that of a healthcare drone, a search and rescue drone, an educational drone, and a spiritual drone. It argued that this powerful technology requires high levels of ethical analysis and responsibility, and that our moral progress must keep pace with our technological progress. It attempted to demonstrate how drone technologies support and diminish the flourishing of certain human values, impact power relations between individuals and groups, and add additional complexity to the network of humans and objects in modern society. Each of these chapters was concluded with an important meta-ethical question: should this drone built? If so, how? If not, why not? Methods that were used to develop the prototype drones – including value-sensitive design, ethical frameworks, capability caution, and speculative design to name a few – were showcased, originating from diverse fields including engineering, ethics, and art. These methods revealed a more subtle and nuanced view of drones than the currently polarized characterization of “the good drone” or “the killer drone”. The book concluded with specific recommendations for drone engineers, companies, social scientists, ethicists, lawmakers, and citizens. These recommendations, and the book as a whole, aim to create better technologies which will support the flourishing of humans and of nature today, and in the future to come.

8 Afterword

The Engineer

Engineering, research, and drone design are performed by people, within a certain context, embedded in a network of institutions, peers, and collaborators. Engineering research is usually approached from a positivist world view (see "World View"), which requires distancing the researcher from the subject matter. For example, research is usually written in the third person "it was found that…" rather than the first person "I/we found that…" An advantage of this approach is that it emphasizes good research can be reproduced by other engineers or scientists – a key to the scientific method. However, a downside is that the research becomes disembodied from its creators, and risks that contextual, cultural, and human factors are ignored. The constructivist world view can be useful in addressing these limitations (see "World View"). In this afterword, I will utilize a constructivist approach and write in the first person. I will share my background, values, and networks to provide context and give the reader insights into the person behind this text and these prototype drones.[1]

8.1 The Individual

8.1.1 Early Life and Career

I was born in Wrangell, Alaska. My parents, Charlotte and Chris, raised me and my younger sister Dana in a cabin off-grid – without running water or electricity – on nearby Etolin Island. My mom won our property in a lottery – the state of Alaska was parceling up land so it could be settled (and generate tax revenue). My parents built the cabin themselves, financing it using all of my mom's savings. They chose to live in this way for different reasons: my dad was a hippy and part of the 1960s counterculture. He claimed he wanted to "drop out" of society and live with a minimum of money and interference from the government. My mom wanted

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Figure 8.1 Me as a baby with my favorite hammer (left), and now with a more complex type of tool – the Danish healthcare drone (right).

Sources: Left photo by my mom Charlotte Klesman, used with permission. Right photo by me.

an adventure, to live in harmony with nature, and to build up a comfortable life from the ground up.

My parents had lofty goals, but our life in Alaska was a struggle against nature and poverty. Being poor in Alaska means you get a very direct experience of life. In the summers you build and repair machines, cut firewood, and catch fish. In the winter, you try to survive – stay warm, and fight off boredom by reading lots of books. If you wanted to stay warm and well-fed in the winter, you had to chop firewood and go fishing in the summer. It was a low-tech way of living, with all of its benefits and challenges. Even so, at times it felt like we were just barely surviving.

Still, my parents did their best to provide us with a good life. My sister and I got to spend every day with our mom, and with our dad too when he had not gone to work in town. Both of my parents were multiskilled – my dad was a carpenter, blacksmith, machinist, mechanic, and artist; my mom taught horse riding growing up, learned woodworking and building construction, played the flute, and did creative writing as well as being a journalist. We watched and "helped" my mom clean, bake, and sew and we followed my dad into his workshop where he forged steel into knives to be sold in town. Learning, using tools, and building things was an important part of my family's culture. One of my first toys was a hammer, and I was often posed with one for photos (see Figure 8.1).

My sister and I received distance education, proctored by my mom at the kitchen table. I was a shy and sensitive kid, but also stubborn and unable to sit still for long. Most lessons divulged into a war of wills between me and my mom. Looking back on it, I am not surprised – non-conformist parents will probably raise non-conformist kids.

When I was 10, my parents got divorced. The isolation in the cabin, my mom's desire for us to have a good education in public school, and, most importantly their different aims in life were major factors. My mom moved us away, first to other parts of Alaska, and eventually to the Midwest. My sister and I spent the summers with my dad in Alaska with few rules, living the life of impoverished bohemians, and the school years with strict rules and high academic standards as part of "normal society" with my mom and stepdad Norris. We got to experience different systems of values, ways of being in the world, and of interacting with our environment and other people.

As a teenager, I started designing and building remote control airplanes. I was – and I still am – amazed by the magic of flight. I invented new model airplane designs and would spend weeks in the basement cutting out delicate pieces of balsawood, gluing them together, and covering them with plastic film. Test flights often lasted only seconds before the object of my obsession smashed into the ground, splintering into thousands of pieces. I sought out my first engineering book, *Model Aircraft Aerodynamics* (Simons, 1983), unknowingly setting the stage for a future aerospace career.

I also began working. Poverty had been hard on me – I hated the feeling of powerlessness, and the teasing from kids at school when I didn't have cool toys or clothes. I vowed to get a good job and to have the nice things that we couldn't afford when I was a kid. Luckily, my mom made sure I applied for scholarships and colleges after graduating from high school. Thanks in large part to her high academic expectations of us, I had good grades and was accepted into a few engineering schools including Georgia Tech and the University of Minnesota, Duluth. I decided to take the latter, less expensive option, and eventually (after six years) worked my way through my bachelor's degree in mechanical engineering.

After graduating, I got jobs in the aerospace industry – first, at the Boeing aircraft company as a manufacturing engineer on the 777 jetliner, and a few years later at the prototype aircraft and spacecraft company Scaled Composites in the desert of Southern California. I rented fancy apartments, and bought a fast motorcycle, and a black convertible sportscar. At first it was exciting and exhilarating to be out of poverty, but soon the glamor wore off. I passed through the poor neighborhoods in my nice car; it didn't seem fair that I now had so much and the people there had so little. I worked all the time and had left my family and friends behind, leaving me sad and lonely. From a materialistic standpoint, I had achieved the American Dream, but I was unhappy.

I had to make a change. I decided to move out of the desert and rented a room in Hollywood. I met a talented musician from Denmark, and we started dating. Eventually I relocate to Denmark so we could be together, and so I could experience more of the world than the inside of aircraft factories. I liked Denmark; it was a calm and orderly place with a low level of poverty and a high level of social equity. Slowly, my values shifted from pursuing self-interest and materialism, to thinking about others and trying as best I could to give back to society. The American Dream had not worked for me, but maybe the Danish Dream would.

8.1.2 Education and Professional Experience

Today, I am Associate Professor at the Drone Center at the University of Southern Denmark.[2] My aim is to support human flourishing through the development of ethically informed technologies. My main area of research is using value-sensitive design methods and ethical principles to develop and build prototype drones for humanitarian, public healthcare, and search and rescue operations. I work across disciplines, utilizing art, craft, and creativity to enhance engineering practice. A common theme in my work is the use of holistic and contextually situated technological development. I consider myself an activist engineer and aim to support less powerful stakeholders, protect nature, and preserve the environment. In my free time I teach and perform repairs with the local nonprofit organization Repair Café Odense, and volunteer with Engineers Without Borders Denmark to develop low-cost fabric masks and mapping drones for use in Africa.

8.1.3 Designer Values

Designer values are “the personal and professional values each designer brings to research and design work” (Friedman & Hendry, 2019). In 2019 and 2020, I collaborated with a colleague to identify my designer values using action research (Andersen & Cawthorne, 2021) .

> Action research is an orientation to knowledge creation that arises in a context of practice and requires researchers to work with practitioners. Unlike conventional social science, action research’s purpose is to effect desired change as a path to generating knowledge and empower stakeholders.
>
> (Bradbury-Huang, 2010)

One of its strengths is in scientific transparency – the objectives of the researchers are made explicit, avoiding hidden agendas. In the study, the objective was to try and bridge the theory–practice gap between ethics and engineering using VSD. The results of the study – the values and virtues I practice in my work – are summarized below:

- The value of autonomy – "the ability to decide, plan, and act in ways that allow one to achieve their goals" (Friedman & Hendry, 2019).
- The value of justice – "obligations relating to issues of distributive justice, special protection of vulnerable groups, avoiding exploitation, and to just procedures" (Van de Poel, 2016).
- The virtue of curiosity – "simultaneously exploring the problem and exploring possible solutions" (Steen, 2013).
- The virtue of creativity – "develop different solutions and articulate goals and objectives…and implement these solutions" (Steen, 2013).
- The virtue of cooperation – "communicating with others during research and design activities" (Steen, 2013).

These values and virtues seem to align with my background.[3] The value of autonomy connects well with mine and my parent's non-conformity and desire for independence. My negative experiences of poverty, and of wanting to help others experiencing it, align with the value of justice. I learned about curiosity and creativity at an early age from my parents. And, later in life, I began to appreciate cooperation and the joy that comes from working together.

It should be noted that I am not proposing a person must grow up off-grid in a remote cabin in Alaska and experience the disillusionment of the American Dream in order to practice VSD. In fact, I believe that the skills necessary to practice VSD are just those – skills. They require some theoretical knowledge (i.e. what are human values, how do they relate to the design of technology), but otherwise VSD is a methodology just like many others that engineers acquire. Anecdotally, I have supervised a number of students that have no prior exposure to VSD and have middle-class Danish backgrounds, which were quickly able to utilize VSD. VSD is a skill, and not a "way of being". This gives me hope that – given a more holistic education – future engineers can become more socially aware and responsible.

8.2 The Context

I do not work in a void – my activities take place within a context, embedded into a network, together with a number of collaborators.[4] I am a member of the University of Southern Denmark Drone Center research group. The group was formed in 2015 amid a lot of excitement over the financial opportunities that drones could offer. The Danish state – spurred on by projections which predicted huge job growth from an aggressive policy of drone development (Wessel, 2015) – invested heavily in the technology.

Our research group currently consists of about 20 employees with various areas of expertise relevant to drone development and operation. The aim of our group is to perform "research, education, innovation, and collaboration in the UAS domain for the benefit of society" (SDU, 2022). This mission statement was formed by myself and several of my colleagues who want to design and use drones to make the world a better place. This mission statement is in contrast with one that is purely technical in nature. It means that we must take a holistic approach to developing technology, and consider the social and ethical impacts of our engineering decisions.

8.2.1 Collaborators

To a certain extent, a scientist is as good as their collaborators and their network. However, engineers and researchers are sometimes presented as isolated from their context and collaborators, producing a misleading narrative of the of the individual "brilliant scientist". Thomas Edison is a classic example, with the *Washington Post* at the time calling him a genius ("Genius before science," 1878). Although often credited with the invention of the electric light bulb – a technology purchased and then painstakingly developed to make reliable – if anything, it was Edison's establishment of an industrialized research lab for collaborator/employees that was the best invention.

The designer values research (designer values) pointed to the importance I place on the virtue of cooperation, and my work would not have been possible without the collaborators I have had the good fortune to work with. This is not an exhaustive list, but what follows are some of the collaborators that have had a significant impact on my personal and professional development.

Aimee van Wynsberghe-Robbins eventually became my PhD mentor and was one of the first researchers working with VSD and drones. In one work, Aimee and her co-author give the example of drones used in policing (Van Wynsberghe & Nagenborg, 2016) to perform either "dull" policework such as patrols, or dangerous work such as riot control. The authors argue that drones should not be used for routine patrols – an opportunity for the police to engage with and gain the trust of the local population. However, drones might be useful in dangerous policework as long as they cannot be used for covert surveillance. Therefore, the drone should be brightly colored, have flashing lights, and other features, which make it very difficult to use for spying – by design. For some reason, this specific example resonated with me, and the seed of understanding the inherent relationship between design and values was planted.

Ibo van de Poel's paper *Translating Values into Design Requirements* (Van de Poel, 2013) was specific enough – with its example of designing a chicken coop that supports the values of animal welfare, human well-being, and environmental sustainability – to have significant influence on my conceptualization of human values and their relationship with engineering. At Delft during my PhD studies, me and the other students had a recurring joke: every time we thought we had come up with a great idea for a research paper, someone would say "Ibo did it". Ibo is a prolific researcher and writer, and has covered most of the important topics in applied engineering ethics over the years.

Alf Rehn was my PhD supervisor, and his subversive perspective, questioning of the technological, and critique of positivism was captivating. Alf exposed me to a number of seminal philosophical and constructivist works. *Do Artefacts Have Politics?* (Winner, 2017) showed how distributed systems – like household solar power – align with democratic values, while centralized systems – such as nuclear power plants – support the centralization of power. *What is it like to be a bat?* (Nagel, 1974) highlighted the subjectivity of experience, an often-neglected topic in engineering. Since my PhD studies Alf's influence has continued, including giving me advice on this book.

Stig Børsen Hansen is a philosopher of technology and a colleague at the Center for Culture and Technology. Stig is a close friend now and is willing to "get his hands dirty" by engaging with engineers and practicing applied ethics. Stig introduced me to important texts on the history of technology (Schatzberg, 1999), which inspired research into high-performance drones made from wood (Cawthorne & Iversen, 2021) (see Chapter "The Search and Rescue Drone"), as well as philosophers of technology like Marcuse with the idea of the "one-dimensional man" and Marx's conceptualization of technology as an extension of class struggle. Stig and I have written several funding applications, taught courses and given talks together, and dream of establishing a Collective for Ethics and Engineering one day.

My students have also been fantastic and fruitful collaborators. I developed the idea of capability caution with my master's student Arne Devos (Cawthorne & Devos, 2020). Christian Dalum Tinggaard and Frederik Haubjerg Larsen helped develop the privacy-preserving camera system on the Danish healthcare drone (Tinggaard & Larsen, 2021), and Andreas Aagaard Asmussen and Nikolaj Pihl Thomsen collaborated on the search and rescue drone (Asmussen & Thomsen, 2021). Students from the product development and innovation (PDI) master's program have helped me conduct empirical work that contributed to a preliminary understanding of the Danish perception of healthcare drones (Cawthorne & Frederiksen, 2020).

Although I have not met them, there are people whose writings have informed my perception of technology. One is Escobar in the book *Designs for the Pluriverse* (Escobar, 2018) where an alternative future – attuned to social justice and environmental sustainability rather than one driven by subjugation and capitalism – is outlined. Dunne and Raby's beautiful and compelling book *Speculative Everything* (Dunne & Raby, 2013) provided a foundation upon which a much different conceptualization of technology could be formed (Cawthorne & Iversen, 2021). Choi-Fitzpatrick's examples of "good" uses of drones to support social movements in *The Good Drone* was both useful and inspiring (Choi-Fitzpatrick, 2020).

8.2.2 The Network

There are several centers of technology ethics, VSD activity, and robotic art around the world that make up the network I am lucky enough to be a part of (see Figure 8.2). I am a member of the leadership group in the Center for Culture and Technology ("University of Southern Denmark Center for Culture and Technology," 2023) and have been appointed by the Faculty of Engineering as a member of the university's Research Ethics Committee ("University of Southern Denmark Research Ethics of Southern Denmark Research Ethics Committee," 2023). I was elected as a region representative to the Danish Engineer's Union as a member of the Youth Party ("Nationwide supplementary mandate list – The youth party (translated from Danish)," 2022) on a platform of sustainable development, good working conditions, and ethics in technology. These roles help me to better understand the inter-relationships of technology with culture, society, and politics – and hopefully, to be a good engineer that can make things which support the flourishing of people and of nature for years to come.

8.3 Future Work

As a young engineer, I firmly believed that technology would save the world. I would help make cargo jets, high-altitude launch vehicles, and drones which would move technological progress "forward" – and moving things forward was unequivocally good. Now, I am much less certain. The interplay between technology, society, and ethics is complex and ever-changing. With each new technology, there are winners and losers – and drones are no exception. Sometimes it even makes me question my chosen career path: is dedicating my life to aerospace and drones the best way to make the world a better place? Could my skills be better used elsewhere? Should I opt-out of this high-tech push, and return to the simple, immediate lifestyle – the way I grew up in Alaska?

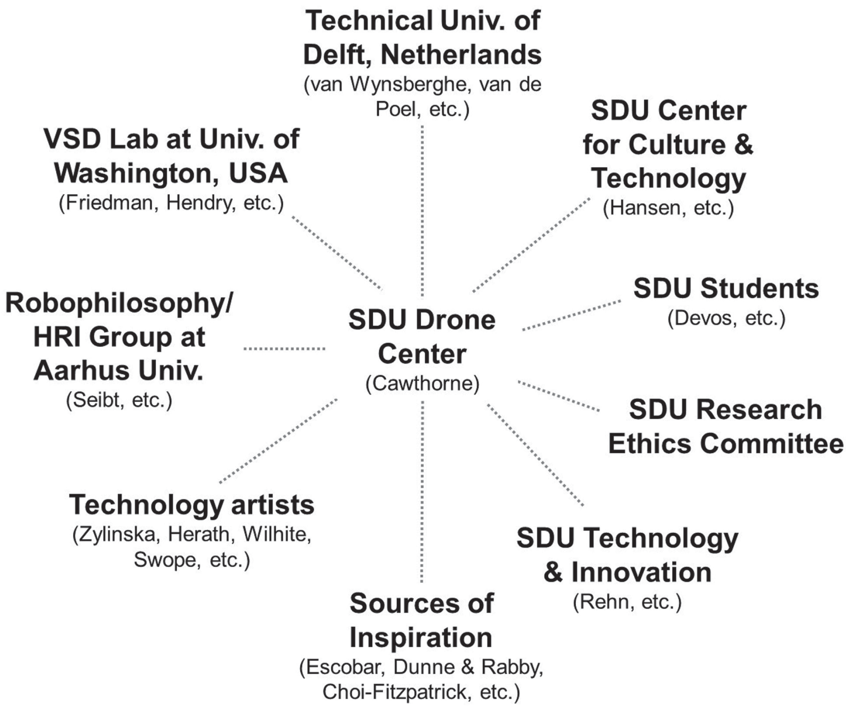

Figure 8.2 Some of the network that the author is a part of.

Source: Graphic by the author.

At this point, I see social and paradigmatic change as more important to the future of value-sensitive and ethically informed design than developing specific technological drone "solutions". I have pursued the prototypes in this book in a genuine attempt to build good drones, and although it has been a fascinating and rewarding exercise, barriers to such drones and to the uptake of a VSD approach are widespread and robust. It is in the *applied* ethics – the practice that attempts to span the theory–practice gap – where things seem to fall apart for ethically informed technology development, and which need the most attention. Hopefully, this book can play a small part in bridging the theory–practice gap, shifting paradigms, and creating better drones. The subtitle of this book claims that value-sensitive design creates better technologies: drones that *perform* better, and drones that are better from an *ethical* perspective. But it will take a concerted effort from various parties to upend the entrenched barriers to its adoption.

My hope is that my fellow engineers can be a key part of this effort. My dream is that we could even lead it.

Notes

1 In this chapter, I write in the first-person to emphasize the subjective aspects of this research, and of research in general.
2 This paragraph is based on the bio for a book chapter I recently wrote (Herath & St-Onge, 2022).
3 To spare the reader an exhaustive recount of my entire backstory, I have chosen to include parts of my early life and career that are relevant to the designer values identified later in my life.
4 To learn more about social constructivism and the importance of context on "objective" science, see Latour (1987) and Latour and Woolgar (2013).

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