Safety and Security:

Architectural Considerations for Autonomous Surveillence Vehicles

Maggie George

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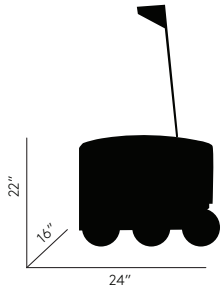
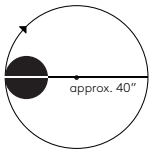
Mobility Typology

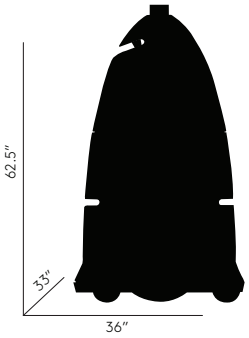


Starship Robot

Speed: 3 mph
Weight: ~35 lbs

Turning Radius:

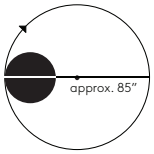


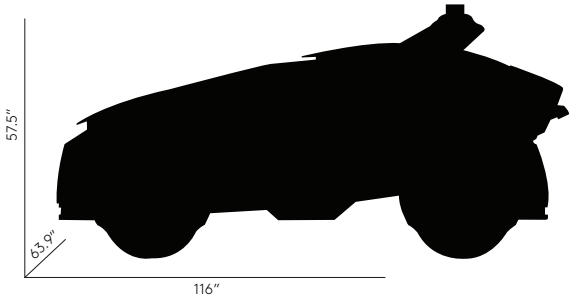


Knightscope K5

Speed: 3 mph
Weight: 398 lbs

Turning Radius:

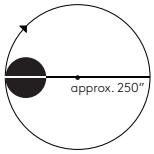


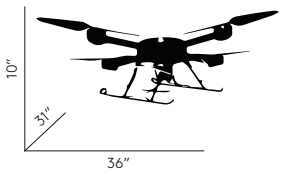


Knightscope K7

Speed: ~7 mph
Weight: 770 lbs

Turning Radius:

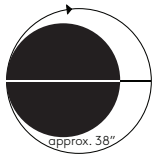


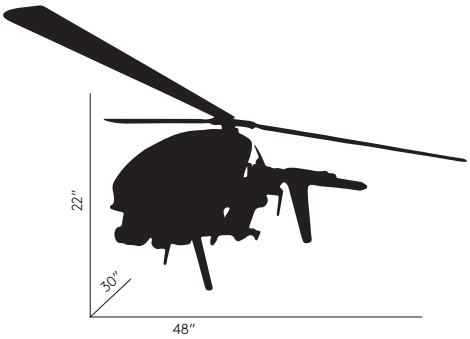


Nightingale Blackbird

Speed: 20 mph
Weight: 9 lbs

Turning Radius:

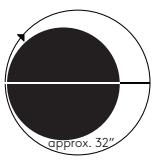


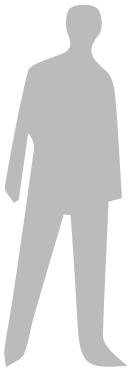


Little Ripper

Speed: 40 mph
Weight: 85 lbs

Turning Radius:





Each machine pictured serves as an example for other autonomous security vehicles that share similar dimensions and functionality. Additional information for each device can be found on the respective company websites. Proximity allotment restrictions were determined from 2018 FAA regulations.

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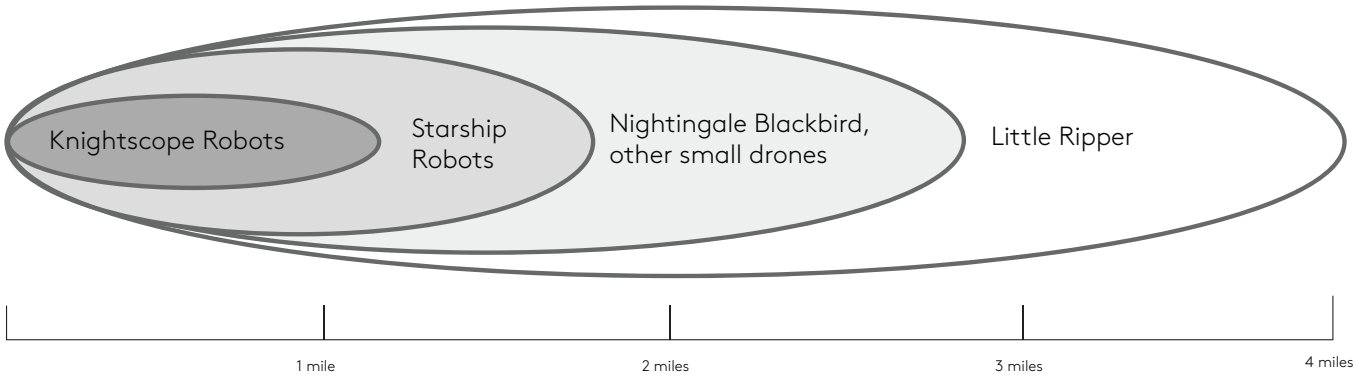
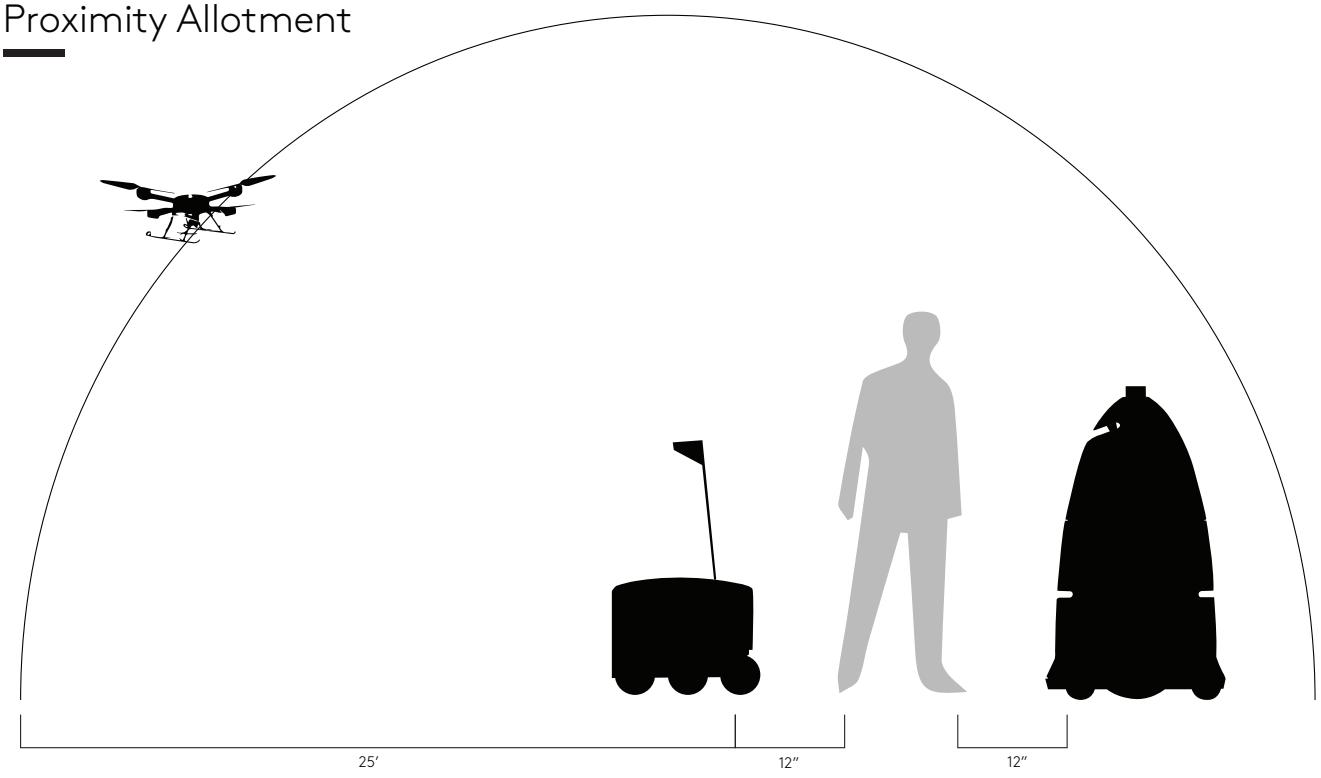
Mobility Typology

Ranges



Proximity Allotment



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ROBOTS IN SOCIETY

In the last two decades, the long-awaited promise of autonomous consumer robotic systems has transitioned to the stuff of reality. Rapidly expanding computational power, combined with reduced price (as per Moore's law), has resulted in a new wave of aerial drones and terrestrial robots built for inclusion into our homes, cities, and social fabric. The consumer robotics market is still relatively young and rapidly expanding, which brings both exciting new opportunities and growing pains. For many who might benefit from the integration of robotic systems into businesses, homes, and society, the role that robots will play is still relatively uncertain. It is clear, however, that whatever path these technologies eventually take, autonomous robots are here to stay.

Aerial drones, which for the purposes of this essay I will refer to simply as drones, have enjoyed a particularly rapid expansion in a host of industries. They are presently used in applications as diverse as military defense, concert production, civil engineering, re-forestation initiatives, photography, sports, and more. It is unsurprising that agile flying cameras would be so universally useful. However, as quickly as drones have been applied to every industry one can think of, protocols and regulations have sprung up to combat the onslaught of drones. Concert-goers frequently bemoan the enormous number of small, buzzing drones overhead, rising above the crowd to get stunning aerial video. National parks around the United States have either expressly banned drones, or have put up a host of signs declaring "no drone zones" at scenic overlooks. Washington D.C. is entirely drone-free. Disgruntled neighbors have been known to shoot down drones on more than one occasion. Aside from being an annoyance, drones are also considered a significant security risk for many of the world's most secure buildings. In the Netherlands, police train hawks to take down criminal drones; for fear that they might otherwise be used for robberies, unsolicited photography, or terrorism[1]. The inclusion of terrestrial robots has progressed more slowly, but nonetheless will likely spawn a similarly significant wave of innovation as compared to drones. Terrestrial robots have long been applied to simple settings, like the playful mobile trashcans in Disney's tomorrow land. More recently, many companies are in the process of testing terrestrial robots for delivery, transportation, and security purposes.

It is a safe assumption, then, that the introduction of terrestrial robots and drones into every walk of life will continue to pick up speed. Therefore, architects and designers should not consider whether or not robots will be present in our shared spaces, but instead should consider in what way.

Of the introduction of robots and drones into the everyday rhythm of society, few instances are as controversial as the use of drones and robots for security applications. Security needs are already a

1 "Eagles Trained to Take down Drones." BBC News. March 08, 2016. Accessed May 09, 2018. http://www.bbc.com/news/av/world-europe-35750816/eagles-trained-to-take-down-drones.

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common flash point of tensions between opposing groups. Including robots into the mix only serves to highlight the depth and nature of those tensions, and so it is a particularly relevant microcosm of human-machine interaction for developing a larger understanding of how robots will live in our society going forward. In the following sections, I will explore the security needs that may be met by robots, the use of robots in those settings, and the possible implication of these human-robot interactions on designs going forward.

SECURITY NEEDS IN THE BUILT ENVIRONMENT

Before delving into the role that robots currently play in the sphere of security, it is pertinent first to briefly describe what security needs robots might address. These needs fall roughly into four main categories, which are helpful in considering what autonomous surveillance technologies would be applicable in each setting. First, there is the single family home, for which physical barriers, alarm systems, alarm system signs, dogs, and the occasional camera are used to deter intruders. Second, there are office and apartment buildings, many of which employ a security guard or a night-shift receptionist in addition to standard alarm systems. On a nightly basis, the security guards are tasked with watching camera feeds form cameras around the building and making rounds of the building perimeter to watch for intrusion. During the day, security guards are responsible for controlling the flow of people and goods in and out of a building, and offering protection for those who work and live inside the building. In larger buildings, unlike smaller family homes, security measures are not only reactive (i.e., a loud alarm), but also combative, as security personnel are often empowered to administer force if necessary. Third are specialized and highly protected buildings, for which the security needs are exceptional. This includes establishments like embassies, sensitive government agencies, government buildings, airports, highly secure R & D departments, banks, and increasingly some schools and hospitals. In these buildings, personnel access is often restricted by a system of keycard access, and entry points for the building are strictly controlled. The building is often "smart" in the sense that individuals carry an ID so that the building "knows" who they are, who is in the building, and who has access. Metal detectors and other invasive visual techniques are also employed in these settings, along with an extensive security personnel forces. Fourth are temporary built spaces that need flexible security, a specialized setting that is particularly apt for use of autonomous surveillance. Because temporary built spaces like music festivals and fairs have little existing infrastructure, autonomous vehicles not connected by integrated building wiring are particularly well suited. In all instances, it is helpful to bear in mind that by far the biggest contribution of security systems on a daily basis is not their express use, but rather their presence as a deterrent. The primary role of a security guard is simply to be in a space, and watchful, as both a deterrent to criminals and a source of comfort for whomever or whatever needs protecting.

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CURRENT USES IN SECURITY SETTINGS

Presently, a number of companies have produced consumer surveillance drones and robots that are now employed in establishments around the world. Here, I have grouped them by the primary roles these robots play. Each of these machines is suited for both deterrence and surveillance, but many are marketed as one or the other.

Deterrence

Among innovations in terrestrial robots, Knightscope, a company based out of California, is one of the most notable[1]. Their series of surveillance robots are fairly large, built to be about the size of a human, up to the size of a golf cart. They are completely autonomous, are presently being tested in malls and plazas. The indoor surveillance robots from this company are sleek towers mounted with visible cameras, which autonomously rove around crowded spaces. Though more cameras are useful in surveillance, the buildings the knightscope robot occupies already have many cameras for catching shoplifters. The knightscope's innovation is, instead, presence. The large robot has an ominous feel to it, and its "eye" is always watching. Humans in the environment around it treat it with caution, and typical give it suspicious stares and a wide berth. In this way, it serves mainly as deterrence, and is treated as a machine not to be trifled with.

In a similar fashion, mid-sized autonomous surveillance drones are effective not only for remote surveillance, but also for deterrence (for an example, see the Nightingale Blackbird drone)[3]. The purpose of these midsized drones is to replace security personnel over a large open-air area, like a shipyard or a storage facility. These drones significantly increase the area that can be surveyed for a given time, and are an excellent tool for surveillance. For the places this technology has been deployed so far, though it does provide an easier means of surveillance, the main benefit it provides is a feeling of security. In this way, the monetary value of a surveillance drone primarily comes from its ability to deter invasion.

Surveillance

Mid-sized surveillance drones offer an excellent means of surveying a few acres of land. They allow mobile video feeds to be delivered back to a human operator, and can even leverage machine-learning opportunities to spot unwanted intrusions autonomously.

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2 "Home." Knightscope, Inc. Accessed May 09, 2018. https://www.knightscope.com/.

3 "Use Cases." Nightingale Security | Robotic Aerial Security. Accessed May 09, 2018. https://www.nightingalesecurity.com/use-cases/.

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Longer-range surveillance drones are particularly useful for their surveillance capabilities, as opposed simply to being a deterrent for illicit activity. Presently, long-range drones have been used to catch poachers and protect African wildlife[4] . Relatively quiet, less obtrusive than a human crashing through the bush, and with the capability to see miles of terrain at a time, long-range surveillance drones and an indispensable tool presently being used in a wide range of settings. They are now wildly used by the military, and are also used to combat drug trafficking. Recently, two people were saved from the waters off of Australia with a long-range drone, highlighting the potential for this format to be useful in search and rescue. Police have occasionally used surveillance drones to track dangerous fugitives, although the practice is currently not widespread. Drones are also used by many fire departments across the country, in order to map out the heat signatures in a building and find victims who may be trapped [5].

Offensive

Drones have also been used as an offensive tool, though they are not currently available for this purpose. Military drones, while never made to fire autonomously, are used in combative situations.

Though it is not a robot or drone, it is also worth noting that autonomous systems are increasingly put to work in digital spaces. Many are fairly harmless-- they decide what ads someone might see on the Internet, or chat with them in the form of a Chabot. However, the application of autonomous artificial intelligence technologies is relevant to the subject of security and surveillance robots, and so it is important to include it in discussion. Currently, artificial intelligence software is used in courtrooms across the country to decided the length of parole for individuals charged with a criminal offense, and in some cases, it is also used to determine sentencing. Because the data fed into this particular software is from racially biased police reporting, the software has been shown to provide extremely racially biased predictive scores for the likelihood of an individual to commit another crime. As will be discussed shortly, these technologies, when put on the offensive, are fraught with potential ethical difficulties because of their tendency to reflect all human biases, both positive and negative.

THE HUMAN SIDE: HOW PEOPLE INTERACT WITH SECURITY ROBOTS

People in public spaces interact with surveillance robots differently depending on whether or not they feel they are the subjects of surveillance, or if they are being protected by it. For example,

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4 Nuwer, Rachel. "High Above, Drones Keep Watchful Eyes on Wildlife in Africa." The New York Times. March 13, 2017. Accessed May 09, 2018. https://www.nytimes.com/2017/03/13/science/drones-africa-poachers-wildlife.html.

5 Findling, Deborah, and Jeniece Pettitt. "How Firefighters Are Using Drones to save Lives." CNBC. August 27, 2017. Accessed May 09, 2018. https://www.cnbc.com/2017/08/26/skyfire-consulting-trains-firefighters-to-use-drones-to-save-lives.html.

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people in malls where Knightscope surveillance robots are deployed treat the robots with slight unease. The robot itself successfully navigates semi-crowded public spaces, so long as those public spaces do not require unidirectional movement of people. The robot is easily avoided, and avoids obstacles in its path relatively well. In this instance, it effectively provides deterrence for shoplifting and other criminal activity by ensuring the that surrounding crowds feel the surveillance system in the building has agency.

The Knightscope robot performs well in malls, however, it has also been deployed in office and city settings, with much more ambiguous results. In 2017, the San Francisco SPCA recruited a knightscope robot to reduce the number of break-ins at the shelter [6]. Just outside the SPCA building in San Francisco's Mission District was an extensive and semi-permanent homeless encampment, running along the sidewalk next to the shelter. When the knightscope robot was introduced, it patrolled the perimeter of the building, up and down the sidewalk.

Immediately, it attracted negative responses from the residents of the homeless encampment along the sidewalk, who threw trash and it, kicked it, and yelled at it. The homeless encampment eventually moved entirely due to the unease created by the knightscope robot. The break-ins to the shelter were also significantly reduced. One might call this a success story, but it was extremely ill received in the city of San Francisco. Residents of the city were appalled with the use of a robot to deter and relocate the homeless population living near the SPCA shelter, and took action through the San Francisco city council to ban knightscope-style robots from the streets. It was argued that it was "inhumane" to use a robot as deterrence. The response of the residents of San Francisco indicates that there are deeper social concerns with the introduction of autonomous surveillance systems than simply their intended effects as deterrence and surveillance. When the visible human element of security systems are removed, it creates clear anxiety over the role and potential decision making that may be carried out by a non-human autonomous security force.

Similar issues arise with the introduction of drones to the surveillance systems of many cities. Though not mediated by drones, many strides being made in the realm of mass-surveillance in Asia severe as useful indicators for how human-machine interactions may play out in the future world of security drones. China has recently introduced a system in Shenzhen that monitors residents using facial recognition software, and logs their behavior. This system, intended to reduce crime and increase the empathy between city residents, has predictably been the subject of global outrage. Much of the ire around this technology touched on fears of a "surveillance state" in which every

6 Farivar, Cyrus. "After Backlash, Animal Shelter Fires Security Robot, "effective Immediately"." Ars Technica. December 14, 2017. Accessed May 09, 2018. https://arstechnica.com/tech-policy/2017/12/after-outcry-non-profit-stops-use-of-security-robot-to-oust-homeless/.

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move is tracked and watched by the government in power.

HISTORICAL CONTEXT

To fully understand why residents in San Francisco were so appalled at the presence of wheeled surveillance robots roving around their city, and why there was such an outcry over China's new citizen surveillance system, it is important to consider the historical context that shapes society's collective perception of machines and security. One has only to consider a few major pop-culture icons to understand how "security robots" might come to mind. Movies like the Terminator, the Matrix, and iRobot paint machines as anti-human, devoid of the ethics, and to be treated with suspicion. Indeed, some companies bank on this connection to pop culture in order to make their robots more of a deterrence. It is likely no coincidence that Kightscope security robots resemble daleks, killer robots from the popular Doctor Who TV series.

Similarly, our culture has long been inundated with cautionary tales of a surveillance state. In the late 18th century, philosopher Jeremy Bentham proposed the Panopticon, a prison organized around a central watchtower [7]. The watchtower was to be lit such that the prisoners in the cells around the tower could never see if they were being watched, and so, Bentham proposed that they would always behave as if they were being watched. Foucault later built on this model, writing "He who is subjected to a field of visibility, and who knows it, assumes responsibility for the constraints of power; he makes them play spontaneously upon himself; he inscribes in himself the power relation in which he simultaneously plays both roles; he becomes the principle of his own subjection. [7"] The Panopticon has since become a popular trope in science fiction writing, as well as in discussions of surveillance state dynamics and how it changes human behavior. The book 1984, in which individuals live in a police state with cameras in every home and office, also plays off the concept of machines used for surveillance that eventually result in total government control. 1984, along with similar literature, was inspired by real authoritarian and/or communist regimes with developed police states, like Nazi Germany, communist Russia, and Mao's Republic of China. Concern over the use of technology to oppress populations is a realistic and reasonable fear.

The most news savvy in our society are also wary of government-sponsored surveillance for the recent and under-reported abuses of it. Revelations of U.S. efforts to survey large swaths of the American population, first revealed by Edward Snowdon[8], are frequently cited in discussions of autonomous surveillance robots in society. Previous and current NSA, FBI, and CIA efforts at mass data collection and targeting of US citizens have resulted in the baiting and creating of radical Islamic

7 McMullan, Thomas. "What Does the Panopticon Mean in the Age of Digital Surveillance?" The Guardian. July 23, 2015. Accessed May 09, 2018. https://www.theguardian.com/technology/2015/jul/23/panopticon-digital-surveillance-jeremy-bentham.

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terrorists from young, isolated Muslims living in the united states. These controversial, extreme catfishing practices are still the subject of serious debate, and have contributed to the view that mass surveillance systems are inherently untrustworthy [8].

This long, rich cultural heritage of considering human interaction with surveillance machines and networks has resulted in a population generally suspicious of state attempts at surveillance. Arguments for and against these practices, as previously noted, take very different tones depending on whether or not the individual in question feels that groups they identify with are being monitored or protected. Mass surveillance of majority Muslim countries by the United States government, for example, is widely regarded as favorable. By the same measure, US citizens are on the whole distrustful of US government agency attempts at mass surveillance. As surveillance and security robots are integrated into the fabric society, it is doubtless that there will be clashes with those who feel they are being watched, and those who feel they are protected by the increased surveillance presence.

DIRECTING THE EXPANDING SURVEILLENCE ROBOT MARKET

There are many legitimate fears surrounding the implementation and use of surveillance robots and technologies, which merit due consideration by designers. It is essential that designers consider these lessons moving forward, in order to direct the advancement of autonomous surveillance technologies in an ethical way.

The technologies we create are reflections of us. Robots that make decisions using large stores of policing data are bound to reflect the racist biases inherent in those large stores of data, which were recorded in part by racially biased humans. The prescription of surveillance robots to a certain area of a city is similarly a biased decision, because humans implemented it. Finally, human use of drones to target and destroy is also an inherently biased act, because of the human making the decisions as they pilot the craft. In essence, the general fear of surveillance robots is not that they will autonomously make bad decisions because they don't possess the "reasoning" of humans, but rather, that they will reflect the flawed reasoning of humans onto a larger audience, thereby granting more power and a greater potential capacity for damage.

Designers must consider the dual need both for security and for freedom, then, as a challenge to create balanced systems. Above all else, it is essential to design autonomous surveillance robots in such a way that crucial points of contention are arbitrated by humans. Additionally, designers working with autonomous surveillance systems must carefully consider what data is recorded, and what the interests and rights of the surveyed population might be. By considering how and why these

8 Greenwald, G. (2014). No place to hide : Edward Snowden, the NSA, and the U.S. surveillance state (First ed.). New York: Metropolitan Books/Henry Holt.

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precedents of surveillance are set, surveillance technologies will develop with appropriate checks and balances instilled within their networks such that they do not grow into a menace on society.

Designers will, in the near future, be called upon to facilitate drone and robot access into buildings, and to design built spaces both to keep autonomous surveillance robots out. The following prescriptive design practices outline a framework for designing the built environment with surveillance robots and drones in mind.

DESIGNING THE BUILT ENVIRONMENT FOR SECURITY ROBOT INTEGRATION

Security and surveillance robots presently take many forms, and so designing buildings expressly for their integration requires many affordances. When designing a building for human-sized terrestrial security robots, most considerations and affordances already in place for ADA accessibility also allow for access by the robot. The more difficult integration may be surveillance drones. Surveillance drone systems will likely make use of other drone access points integrated into buildings to make delivery of packages more streamlined. In order to seamlessly integrate into the building, autonomous surveillance drones must have the proper building apparatus to fly in buildings, and must be separated from the human populations of a building. Additional considerations for security drones and robots inside buildings are outlined in the following pages.

DESIGNING THE BUILT ENVIRONMENT FOR SECURITY ROBOT RESTRICTION

In addition to making buildings more accessible to security robots, there is also a need for building design protocols that restrict drone and robot access. Of the ways to accomplish this, one of the most effective will be to carefully construct the guidance systems for drones in a building such that they are only able to operate in a certain region. Because drones and other autonomous robots often require signal extenders for Wifi and GPS to function inside buildings, the strategic placement of these may effectively impair the robot's movements through a building, as easily as it can facilitate it. In outdoor and temporary built spaces, Wifi jammers may be used to hinder the recreational use of drones. Finally, physical architecture will also play a significant role in restricting access of surveillance robots to buildings. If buildings are integrated with channels for drones, for example, reducing or removing these access points also restricts the potential for surveillance. Window material composition and polarization may also be leveraged to hinder the visual capacities of any uninvited drones. If all else fails, surveillance drone restriction may be accomplished by apply netting around buildings and public spaces.

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Opportunities for Architecture

BUILDING OPPORTUNITIES

• "Fencing" may go horizontal; netting needed to cover sensitive spaces and keep them drone-free.
• Upper-level building envelope openings may be recruited for new drone access points.
• Roof access may become a priority space, and be used as a landing pad for drones.
• ADA accessibility will be pushed to the forefront of design practice, instead of an afterthought, because many ADA accessibility guidelines pertain to robots.
• Buildings will become more effective and monitoring themselves, as smart systems become integrated.
• Mail and other small goods may travel through visible overhead ceiling ductwork within large buildings.
• Building facades, especially of luxury apartment buildings, may adopt tile work or patterning to confuse certain camera systems used for drone guidance.
• Polarized or mirrored windows may become more popular for increased privacy as drones fly past higher floors. Upper floors will become less private.

DIGITAL

• Drone or terrestrial robot drive surveillance will facilitate faster adoption of chaotic storage models for warehouses, because there will no need to maintain pathways for humans—drones can just fly over, and terrestrial robots can circulate through.
• Building networks will become smarter and more integrated to control the flow of autonomous systems in and out of the building. Autonomous systems may access the building network through an ID, similar to personal computers.
• Elevators may change to be able to communicate with robots, and carry them between floors like humans.
• Buildings will be able to call the police or emergency services if surveillance systems see abuse, or see someone suffer a medical emergency.

HUMAN

• Packages will arrive at the roof, not the ground floor, which may change the dynamic of some apartment buildings. i.e., the penthouse may no longer be desirable.
• People in cities may wear more face-recognition obscuring fashion, make-up, and glasses to protect their privacy.
• Security guard jobs will shift to even more camera-watching time, as well as involve maintaining robots. There will be fewer security guards overall.

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Hypothesis

EQUATION

10 ft ceilings + additional 2.5ft for drone clearance in buildings + 0.3 feet for material thicknesses and wiring = 12.8 ft main hallway ceiling heights to allow for separate surveillance drone corridors.

FUNCTIONAL CHANGES

- The simplest way of integrating drone pathways into a building is to assume all drones are autonomously guided, and access the building from rooftop through vertical shafts adjacent to elevator shafts. From there, it is crucial that surveillance drones access major hallways on each floor of the building.
- To limit human-drone interaction and reduce chance of injury, drones should be separated by translucent overhead ductwork running throughout main corridors.
- Because surveillance drones will be employed, there may be no need for security personnel. Building inhabitants may feel a sense of security because they are accompanied by security drones.
- Integrated autonomous vehicle security networks will reduce crime and will make buildings safer in the event of a fire or emergency.