Could slaughterbots wipe out humanity?

Assessment of the global catastrophic risk

posed by autonomous weapons

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**Abstract**. Recently criticisms against autonomous weapons were presented in a video in which an AI-powered drone kills a person. However, some said that this video is a distraction from the real risk of AI—the risk of unlimitedly self-improving AI systems. In this article, we analyze arguments from both sides and turn them into conditions. The following conditions are identified as leading to autonomous weapons becoming a global catastrophic risk: 1) Artificial General Intelligence (AGI) development is delayed relative to progress in narrow AI and manufacturing. 2) The potential for very cheap manufacture of drones, with prices below 1 USD each. 3) Anti-drone defense capabilities lagging offensive development. 4) Special global military posture encouraging development of drone swarms as a strategic offensive weapon, able to kill civilians. We conclude that while it is unlikely that drone swarms alone will become existential risk, lethal autonomous weapons could contribute to civilizational collapse in case of new world war.

**Keywords**: slaughterbots, lethal autonomous weapons, existential risks, global catastrophic risks, artificial intelligence

**Highlights:**

* Drone swarms could become existential risks only under very specific technological and societal conditions.
* Military robotics could contribute to global catastrophic risk in the case of WW3.
* Advances in manufacturing and technology could allow creation of tens of billions of small military drones in the 2020s.
* Defense systems are lagging behind offensive capabilities in military robotics.
* Existence of robotic armies lowers the computational complexity of omnicide.

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*Start*

*10 Find a human*

*20 Kill the human*

*30 Repeat*

*End*

# 1 Introduction

In 2016, hundreds scientists signed a letter against autonomous weapons (Future of life insitute, 2017). In 2017, The Future of Life Institute published a fictional video about “Slaughterbots” (Oberhaus, 2017), in which a small drone weighing around 100 g was able to identify a specific human being, attach itself to his head, and explode, killing him. Later in the video a group of terrorists attacked a university campus with drones. This video has several million views to date and has started a public discussion about the risks of autonomous weapons.

Many great works of fiction have presented the idea of the catastrophic risk of small drones, from “Invincible” by Stanislaw Lem (Lem, 1973) up to a recent episode of *Black Mirror* (Watkins, 2016). ~~W~~hile the concept of killer drones has long been a subject of fiction, it has become a topic for philosophical and scientific discourse as well. Paul Scharre recently wrote an article “Why You Shouldn't Fear 'Slaughterbots” (Scharre, 2017). Tegmark et al. offered a detailed rebuttal, in which they showed that nations may have an incentive to build large drone armies, that defense against drones is not easy, and that terrorists can gain access to many drones and use them to start a coordinated attack (Tegmark, Russel, Conn, & Aguirre, 2018).

Contemporaneously, a Russian military base in Syria was attacked by a swarm of 31 homemade drones, causing millions dollars in damage, though the price was each drone was estimated at only about 200 USD. (Reid, 2018). The problem of swarms of the killer drones was known long before that attack. Freitas wrote about it in connection with the potential for nanotechnology to build weapons such that 50 billion microdrones weighing only 200 mcg each could carry enough botulism toxin to kill humanity—and could be packed in a single suitcase (Freitas, 2006). So, it seems that the existence of microdrones poses a global risk, while current drones obviously do not pose a threat of extinction; where is the threshold of this risk?

There is significant interest in the topic of lethal autonomous weapons (LAWs) e.g. (Boulanin & Verbruggen, 2017), (Jenks, 2017), (Bode & Huelss, 2017), (Haas & Fischer, 2017) (Sharkey, 2017) (Kott, 2018)e.g., and its effects on the future of humanity, but most of the discussion is about the legal and moral aspects of such weapons, not the question of whether drones are capable of causing a global catastrophe, killing all or almost all human beings. Some in the AI safety community have expressed the opinion that LAWS can’t become an “existential risk”, and thus LAWs is only a distraction from the real problem of developing superintelligence (Bogosian, 2017). On the contrary, we have previously outlined that self-improving AI will evolve into Military AI on its own (Turchin & Denkenberger, 2018b).

In this article, I address several questions: Could military robotics present a global catastrophic risk in the future? Under what conditions could this risk arise? Is this risk comparable to the risk posed by superintelligence? I start from the simplified model in section 2, analyze necessary social conditions for creating large drone army in section 3, discuss possible defense mechanisms in section 4, necessary conditions for such a global risk in section 5, the future of military robotics in section 6, and then assess the chances that drone swarms could cause or contribute to existential risk of at least civilizational collapse in section 7.

# 2. Simple model for the risk of drone swarms

## 2.1 How many drones are necessary to kill everybody?

For the start, we created an oversimplified model of the risk of drone swarms that ignores the potential for anti-drone defense and does not account for the motives of the perpetrator.

The current global population is around 10 billion humans, and self-destructing drones could not kill more than one person each. Small drones with a camera are currently available on Alibaba from 30 USD (Alibaba.com, 2018). If such drones were adapted for killing, and are assumed to be absolutely effective killers that will be delivered everywhere, it would still cost at least 300 billion USD to exterminate humanity, an insurmountable amount for terrorists and superpowers, especially as this figure ignores all practical difficulties, such as delivery. Small drones have a short battery life of around 10 minutes, meaning they can’t travel more than 1–2 km, necessitating a large delivery platform, which will be even more costly than the drones themselves. Cheaper omnicidal agents may be available, e.g. biological weapons, which could cost thousands of times less, especially given current advances in synthetic biology (Torres, 2016).

Thus, drones do not currently pose a global risk, but what about 10 years into the future? Extrapolation from current technologies allows a discussion of the ways autonomous drones could become more dangerous by incorporation of new technologies that could appear in the next ten years.

## 2.2 On-board AI systems

The ability to independently target humans will require something similar to autonomous self-driving car autopilot AI. In 2018, a system similar to car autopilot was successfully installed in a drone (Ackerman, 2018), though the best systems of this type currently consume around 500 W of power and weigh kilograms (Ayre, 2017), impractical for drone applications. However, there are ideas about how to lower neural net power consumption 10 000 times (Neal, 2017), though it is expected that at least 5–10 years will be required to create such system on a chip. On-board AI also should be able to communicate with nearby drones to support swarm behavior.

Future radio communication jamming may be more effective, which would increase the drive toward drone autonomy. Even autonomous drones could be made much safer if they have some simple set of restrictions, such as instructions to turn off after ten hours, to not leave a defined area, to avoid attacking women and children, etc. (Aysan, 2018).

## 2.3 On-board weapons

In the Slaughterbot video, a drone attached itself to a human head and exploded a small directed-explosion munition; objections were immediately raised that simple nets could be used for protection against such drones. However, a drone could carry a small one-time-use plastic gun. Its plastic barrel will self-destruct, maybe together with the drone, and its accuracy and the bullet speed will be not as high as in long rifles, but may be enough to cause deadly injury. The firing mechanism will be small and electric. The most suitable ammunition for such a gun is something like a .22 LR cartridge, which weight around 3 g, and could cause deadly injuries, though death may not be immediate (Karger, Teige, & Brinkmann, 1997). The .22LR cartridge is already very cheap, retailing for only 0.06 USD (Cheaperthandirt.com, 2018). Military .22 cartridges have fragmenting bullets that are much deadlier than those available to civilians. A small 3D-printed gun intended for mounting on a drone could be quite simple, lacking the moving parts, grip, and safety mechanisms of standard handguns or rifles.

The smallest current military drone is the Switchblade drone (Hambling, 2016), which carries a grenade able to destroy a light vehicle, weighs 2.7 kg, and has a range of 10 km. In contrast, weapons carrying toxins—like the botulinum-carrying microdrones described earlier—could be much smaller than those armed with projectile weapons or explosives. Freitas found that smallest mass of a deadly microrobot is 200 mcg—the typical mass of an aphid and 0.1 of the typical mass of an ant (Freitas, 2006).

It is easy to imagine a drone capable of killing 10–100 unprotected civilians, equipped with small bombs or a sniper rifle, but it would be rather large, at least 10 kg, and thus more expensive and vulnerable than smaller drones. In an alternate approach, drones may not need any weapons at all to kill; they could use kinetic energy to cause injuries, falling from height onto a human’s head, or they could use their blades to cut throats, damage eyes, etc.

## 2.4 Larger range

Some insects are able to travel hundreds of kilometers without food; for example, locusts are able to travel 5000 km over the ocean with the help of wind (Lorenz, 2009). Birds can make flights of thousands of kilometers. For a drone to be able to do emulate these examples, it needs not electric power, but a small internal combustion engine (ICE). Current small engines for aviation models are available, weighing 400 g with prices starting at 100 euros (lrp.cc, 2018) The current smallest ICE could be put inside a hand watch; it is smaller than a finger nail and 700 times more energy efficient than batteries (Singh, 2011). In terms of cost, a 3g engine is available for 345 USD. Surely, 3D printing and mass production will dramatically lower the future cost of small engines. Fuel-powered small drones could cover hundreds of times more distance than those that are battery powered, so a range of 1000 km seems to be within reach.

## 2.5 Drone delivery systems

Using ICE and fuel could give a drone a range on the order of 1000 km, still not enough to cover the entire surface of the earth. Electrically powered drones could carry photocells for power generation, but such drones will “rest” most of the time and be unable to cross oceans, allowing a chance for human survival on very remote islands (Turchin & Green, 2018). Self-charging drones will probably be limited to traveling 10 km per day, meaning crossing a continent could take several years; however, if they are lost on a battlefield they could roam surface of the Earth for a long time.

Tegmark et al. predict that in the future “most…larger drones are carriers for multiple, shorter-range lethal micro-drones that are deployed automatically in the final moments of the attack” (Tegmark et al., 2018). Photovoltatic-powered autonomous planes could stay in the air for days and travel very large distances, including circumnavigation of the globe (Naval Research Laboratory, 2017). A billion 100 g drones would weigh 100 000 tons, and only large cargo ships could deliver them, but planes are now being tested to deliver swarms of 103 drones (Department of Defense, 2017).

## 2.6 Drone weight

Many parts of a drone are similar to those in a smartphone, including camera, battery, processor, etc. The smallest smartphones weigh no more than 60 g. (Amazon.com, 2018b). So, it is reasonable to estimate that dangerous drone will weigh on the order of 100 g but could be much smaller. The smallest flying robot is currently 2.5 g (Andre, 2016), and the smallest quadcopter available to consumers weighs 11 g and costs 40 USD (Amazon.com, 2018a).

Though it has not yet reached mass production or the commercial market, the RoboBee drone draws inspiration from nature, mimicking insect flight. It avoids the use of classical motors by incorporating piezoelectric “muscles”, and weighs in at only 0.08 g. Though it can’t currently carry effective brains and batteries, in 2017 it was adapted to move through water and cross the water-air barrier (Chen et al., 2017).

Drone sizes will continue to shrink with technological progress, and as we could see in the example of insects, small size is not an obstacle to flying long distances and precisely targeting prey. Moreover, lowering weight corresponds to lowered price in mass production, as it leads to lower costs for raw material and transportation.

## 2.7 Price

A swarm drone-based superweapon becomes feasible only if its price will be a fraction of the military budget of the biggest superpowers. Currently, largest military projects like series of new US SBNN cost more than 100 billion dollars over several years. Though larger expenditures are possible during dangerous periods and economic growth, in any case, 100 billion USD seems to be a safe upper limit for the amount a superpower would agree to pay for such a weapon.

The case of 100 percent efficiency implies a cost of 10 USD per drone, which seems to be in reach, as the cheapest commercial smartphones cost 20 USD and small drones cost 30 USD. Economies of scale, excluding costs for marketing, taxes and profit expenditures, 3D printing of parts and manufacturing automation could further lower the price of such drones, so they will cost 10 USD even without any exotic manufacturing technologies. If we assume the current trends computer hardware pricing and cheaper manufacturing, 1 USD drones seem to be within reach.

## 2.8 Probability of drones overcoming defenses

 As was explored by Russel and Tegmark (Tegmark et al., 2018), defending against small drones is difficult; swarm behavior could even help them make holes in walls. But the main point is that it is possible to provide very high-quality defense only for a small group of people and for a short period. For example, underground bunkers could be ground-isolated for months, but not for longer terms (Baum, Denkenberger, & J, 2015). Drones could penetrate bunkers using airducts, and complete isolation will not last for long. In addition, hard bunkers are likely to be targeted by other weapons in case of war. Only nuclear submarines seem to be well-protected providing six months or more of surface independence (Turchin & Green, 2017)—but even they could be hunted by underwater drones.

So, bunkers would be rare and vulnerable, but makeshift defenses will be also vulnerable. People can’t survive in the basements of their houses for more than a few days. This means that billions of people will not have any defense in case of global drone attack, and only a few thousand would have high-quality defenses. Thus, for most cases, one drone would be able to perform one kill (assuming self-destruction of the drone; non-self-destructing variants could be possible with use of toxic needles, etc.).

When attacking hardened targets—like military ships, bunkers, and air-defended military units—hundreds of drones would be needed for one kill, but even assuming that millions of people are in such military installations, the total number of drones needed to kill them would be on the order of 1 billion, that is, a small fraction of the total number of drones required for omnicide.

## 2.9 Duration of the independent operations

To pose a serious threat, drones would need be autonomous for long periods, from days to years. In that case they could work across long distances or wait for an opportunity to attack. It also means the ability to withstand bad weather. Smartphones can work for years with constant recharging, but they lack the type of mechanical parts integral to drones, which could be more fragile and prone to failure.

# 3. Situations in which an autonomous drone army could be created and implemented

Above we analyzed a purely theoretical model which didn’t take into account motives, social situations, or delivery system, and assumed the existence of only one type of drone.

For something to become global catastrophic risk, by definition it should be able to cover almost all of the surface of the Earth, and able to effectively kill people. In the next sections I explore the ways in which drone swarms could be distributed across the surface of the world and the reasons they might be used against all types of human targets.

## 3.1 Arms race and doomsday weapon

The nuclear arms race created a much larger arsenal than would have been needed to completely crush the enemy; it was expected that in case of an enemy’s first strike, only a small part of the attack would survive and be able to overcome anti-ballistic missile (ABM) defense. As a result, the Soviet nuclear arsenal was around 100 times larger than what would be needed to cause unacceptable damage to US in the absence of defenses. This doctrine of mutually assured destruction (MAD) also played a role in creating exceedingly large nuclear arsenals, and some suggested creation of a stationary doomsday weapon as a universal defense weapon.

The same types of “game theory” arguments could be applied to large drone armies; they then reach the level of strategic weapon and produce much larger military installations which may later be used accidentally against unintended targets.

## 3.2 World war

By world war (WW) I mean an all-out war between superpowers for global domination, which aims for complete destruction of the enemy, and probably on the unification of the planet under one leadership. This last requirement will make the war especially destructive, as all other potential enemies must be eliminated or permanently controlled. The “rationale” behind it is that previous world wars didn’t create a world government; thus, a next world war or wars become possible.

An efficient world war requires creation of weapons which can attack everywhere in the world and perform police functions; such weapons could be only military robotics.

If WW3 occurs in the 2020s–30s, before major advances in nanotech and superintelligence, three types of weapons of mass destruction would likely be used:

* Nuclear weapons
* Biological weapons
* Drone swarms

Military AI is likely to be the common factor behind these methods (Straub, 2018). Each of them individually is unlikely to cause extinction, except in the case of an extreme scenario, as they have different profiles. Nuclear weapons will affect most hardened targets like bunkers and cities, and biological weapons could spill off to most vulnerable populations in remote places because of their wide dissemination. Military drones are somewhere between the two, as they could cause chaos and affect lightly hardened or distributed targets.

## 3.3 Global failed state

The number of failed states in the world—Syria, Yemen, Libya, Somali, Lebanon—is growing (The Fund for Peace, 2018). Such states may continue to exist for decades, like Afghanistan; these states are in constant tribal war, and are a fertile ground in for terrorist organizations to form and grow. It is possible to imagine that if this trend continues, a large part of the world will provide such conditions.

## 3.4 Collateral damage

Around half of victims in current wars are civilians, but these are mostly people who live within a few miles of the field of combat. The distance comes from the typical distance of misfiring f bullets and shells. An autonomous drone that loses its target could cover a much longer distance or wait a much longer time before striking. One analogy is the threat of landmines, which continue to harm civilians years and decades after the end of a war—but unlike drones, mines are unable to move and seek out new targets. In the case of a global war, the battle field will be much less localized, leading to greater collateral damage and more civilian casualties.

## 3.5 Terrorists states and individuals

While one super power creating a very large drone army may seem unlikely, it seems more probable that many small states and terrorist groups will produce many drones to fight their enemies locally, as happened in Syria (Reid, 2018). Tegmark et al also think that individual terrorists could buy thousands and millions of killer drones from future black markets (Tegmark, Russel, & Walsh, 2015). If there are many such terrorists, they could control enough drones to kill almost everybody. The same is probably true for future bioterrorists, as explored in (Turchin, Green, & Dekenbergern, 2017).

## 3.6 A robotic army is needed to consolidate global power

Why deliver robotic drone armies to remote parts of the world? A good example is the current situation in Afghanistan, a battlefield for terrorist, national, and international groups—the Taliban and ISIS, international coalition, drug producers, and local government. This complex net of threats requires airborne drones even now to provide surgical strikes in the most dangerous places. Future failed states could become flourishing ground for terrorists, drug dealers, and even potential bioterrorists. Thus, the capability to deliver robotic armies to the remote places of the world is needed to control risks posed by terrorists and other criminals.

## 3.7 Cyberterrorists take control of robotic armies

One centralized robotic army could be launched accidentally, in much the same way as near-misses have happened with nuclear weapons; control over it could also be obtained by hacking attacks by malevolent agents. Such an attack may include taking control over cars with autopilots (Aysan, 2018) planes, home robots, sex robots, civilian drones, power plants, etc.

## 3.8 More-advanced AI take over existing military robotic infrastructure

Even in the fictional example of Skynet from the Terminator movie (Cameron & Wisher, 1991), the AI started by taking control of already existing nuclear weapons and robots and immediately used this control to attack all humans . While the example is fictional, it is based on a more-or-less rational chain of possible choices.

It is assumed by Bostrom (2014) and Yudkowsky (2008) that future superintelligence will be able to create its own military infrastructure by solving protein folding problem, but it is just an assumption. If it is “mild superintelligence”, called young AI elsewhere, it may have no time to solve protein folding and thus will use existing military infrastructure.

## 3.9 The law of techno-humanitarian balance

Nazaretian has suggested and supported by historical examples a “law of techno-humanitarian balance”, which claims that the more dangerous technologies are available in the society, the lower is the level of inter-special aggression. However, there are several important exceptions (Nazaretian, 2004). For example, when some tribes in Vietnam got automatic rifles, they almost completely exterminated each other, as their society was not able to adapt quickly to the growth of individual “killing abilities”. Thus, if changes in offensive technology are too quick, society may not be able to lower its conflict level in time and could self-exterminate.

## 3.10 Small computational complexity of omnicide in the case of a standing robotic army

As mentioned elsewhere, technological growth is lowering the requirements for AI, which could pose a global risk. The narrow AI virus which could turn robotic army against human beings doesn’t need to be superintelligent. It even could be as simple as several lines on high-level code:

*Start*

*10 Find a human*

*20 Kill the human*

*30 Repeat*

*End*

# 4. Different methods of defense and protection

Shields are orders of magnitude more expensive than attack instruments in cybersecurity and are still not 100 percent reliable (Yampolskiy & Spellchecker, 2016), (Friedman, Moore, & Procaccia, 2010). They appear as reactions to new technologies, so they are, by definition, lagging technologically: there are no shields against the newest technologies. Anti-ballistic missile defense is an excellent example of an expensive and ineffective shield that appeared decades after the origin of the threat.

The general problem of shield and sword in the technological age is that shields are expensive and quickly made obsolete by new technology. If a shield is future-proof, the high price will be less of a problem, as the cost could be distributed over decades. This happened in the Middle Ages, when a fortress was an effective defense against armies, but price of a fortress was distributed over decades of building. As drone armies will be built very quickly, presumably in a just a few years, the expensive protection system will be lagging and not cost-effective.

Table 1. Different defenses systems and their advantages and disadvantages

|  |  |  |
| --- | --- | --- |
| **Defense mechanisms against drones** | **Advantages** | **Disadvantages** |
| Other drones | Effective search | Need larger quantity of drones for effective protection |
| Lasers | Remote engagement, many rounds | Expensive and need straight line of sight |
| Turrets with guns | Tested anti-aircraft solution | Expensive and short distance |
| Nets and fences | Could be made locally | Could be penetrated by repeating attack by swarms |
| Radiofrequency jamming | Prevents coordination | Needs direct-line visibility; power sources, large installation, short distance |
| Underground bunkers | Protects against air drones | Need air supply and will be attacked by other methods during war |
| Submarines | Most protected refuges ever created | Only a few people could survive and would have to create civilization from scratch |
| Remote islands | Drones may be not able to reach most remote island | Only a few people could survive and would have to create civilization from scratch |

# 5. Converting objections into necessary conditions

There are several common objections to the idea that large drone swarms could be a source of global risk. These objections have some grain of truth, so we will try to convert them into conditions when catastrophic risk of drone-swarms (GCRDS) are possible.

1. Objection: Drones are expensive. Condition: Basic drones must cost less than 10 USD—and maybe even less than 1 USD—to become global risks.
2. Objection: Superintelligence will appear before large swarms of drones could be built. Condition: Superintelligence should be delayed or appear to be technically difficult for at least several years after narrow AI at the level of self-driving cars appears and is successfully miniaturized.
3. Objection: Drones’ travel distance is limited. Condition: Only if drones’ distance travel limits are above a thousand km, maybe possible with the use of delivery drones, could they pose a global risk.
4. Objection: It is easy to protect against drones. Condition: Only if drones will able to penetrate defenses using swarm behavior, guns, waiting, and intelligence for searching holes in defenses, will they pose significant risks; they must also outnumber protected targets, and be able to escape direct-attack weapons like lasers and bullets, potentially by moving close to the ground.
5. Objection: It is unlikely that large drone armies will be built and used against large civilian populations. Condition: Drone swarms could become global risks only under several conditions, which include a) ability to cheaply manufacture large drone swarms; b) intense global conflicts and arms races; с) cyberattacks; d) command errors.

Some of these objections depends on the principle directions of future technological progress, which are currently unknown, so they correspond to one of possible future “timelines”, where:

1. Superintelligence and even human-level AI is difficult and will appear at least several years after effective robotic brain.
2. Manufacture of small robots is cheap.
3. The world is in the midst of a cold war, WW3, or global failed state.

# 6. Different types of military robots and future of military AI

## 6.1 Military drone typology

Slaughterbots was just an example to attract public attention. Drones types could be as numerous as live beings or other military equipment, and it is not easy to predict which will dominate. Drone size will depend on the price of manufacturing and the level of miniaturization of AI components. Some possible types of drones are described in Table 2.

Table 2. Types of drones, their advantages and current examples.

|  |  |  |
| --- | --- | --- |
| **Type of drone** | **Specialization** | **Current examples** |
| Bullet-drones | Smart bullet used by other drones to act on short distances | [Smart-bullets](https://www.buzzworthy.com/exacto-smart-bullet-changes-direction-midflight-darpa/), (Stice, 2016). |
| Crawling drones | Secret penetration of protected facilities | [Recon scout robots](http://theweek.com/articles/476995/militarys-new-weapon-mini-spy-robots-throw-like-grenades), (The week, 2012). |
| Flying small drones | Antipersonnel weapon |  |
| Drones with guns | Antipersonnel weapon | [TIKAD](https://techcrunch.com/2017/08/17/a-defense-company-put-a-machine-gun-on-a-drone/), 2017, (Biggs, 2017). |
| Underwater and underground drones | Penetration of protected facilities | Many consumers underwater drones are on [sale](http://www.top10drone.com/best-underwater-drones/) (top10drone, 2018);Underground [Badger robot](https://spectrum.ieee.org/automaton/robotics/industrial-robots/eu-developing-robot-badgers-for-underground-excavation) (Ackerman, 2017). |
| Jumping landmines | A drone to protect certain area, for example, by flying around it | Smart landmine [*Spider*](https://www.textronsystems.com/what-we-do/weapon-sensor-systems/spider), (Textron Systems, 2018). |
| Drones to deliver smaller drones + Drone mother-stations with charging | Larger drones could deliver small drones to the combat field | [Amazon’s](https://www.livescience.com/57416-amazon-patents-flying-mega-drone.html) mother drones for retail (Weisberger, 2017) |
| Autonomous car drones and small tanks |  |  [Self-crashing cars](https://www.zachaysan.com/writing/2018-01-17-self-crashing-cars) (Aysan, 2018). |
| Drones with small bombs |  | [ISIS used consumer drones](https://www.nytimes.com/video/world/middleeast/100000005040770/isis-drone-attack-mosul.html) to target troops with bombs, (Gibbons-Neff, 2017) |
| Walking drones |  | [Boston Dynamics](https://sciencetrends.com/boston-dynamics-dog-robots-can-now-open-doors/) production (Nelson, 2018). |
| Sniper drones |  | ISIS used [robotic snipers](https://www.mirror.co.uk/news/world-news/isis-found-using-robot-controlled-7685347) (Webb, 2016) |
| Drone-hunting drones |  | [Drone hunters](https://gizmodo.com/watch-a-drone-hunting-quadcopter-attack-its-prey-1787762611) (Liszewski, 2016) |
| Drones to deliver biological and chemical weapons  |  | It was suggested that drones could deliver chemical weapons (Dunn, 2017). |
| Drones with small nukes |  | [Nuclear armed drones](http://nationalinterest.org/blog/the-buzz/nuclear-armed-drones-they-may-be-closer-you-think-18034), (Bitzinger & Leah, 2016) |
| Very small drones, less then 1 g |  | RoboBee |
| Microdrones, 1–2 mm in size, with weights of several mg like flies |  |  |
| Laser-equipped drones and satellites |  | [Drones with lasers](http://www.businessinsider.com/laser-drone-missile-defense-boost-phase-intercept-2017-6), (Lockie, 2017). |
| Self-replicating drones using genetically programmed biodrones |  | Planned to colonize Solar System (Chirikjian, Zhou, & Suthakorn, 2002), but could be used in Earth |
| Non-replicating nanorobots of the size of a cell |  |  |
| Autonomous swarm unit, self-sufficient and consisting of many types of drones, including high altitude reconnaissance, mother drones, repair and resupply drones, crawling drones, etc.  |  | Pentagon works on drone swarms (Martin, 2017). |
| Drones with partial self-replication and self-repair abilities | 3D printing, GMO-organisms able to replication  | RepRap 3D printer which prints itself (PerRapPro, 2018). |
| Self-replicating nanorobots with elements of AI |  |  |

## 6.2 Swarm intelligence power

The main power of drones is not the drones themselves, but their ability to act in swarms. This means that groups of drones could implement different strategies and tactics, and also allow the cooperation of drones of different specialization.

## 6.3 New types of manufacturing enabled by narrow AI

There are several main factors which will reduce the price of drones:

1. Robotisation of factories + automation of transportation of the supply lines. Example is Elon Musk’s Gigafactory for battery production, which feeds in raw materials, and creates all details in place, cutting transportation costs.
2. Printing of the main parts of drones + 3D printing of complex parts like engines.
3. Lithography of small mechanical parts. Computer chip manufacturing allows the creation not only of integrated circuits, but also of micromechanical components, called MEMS (Guckel, 1996).
4. Partial self-replication of factories. A large factory capable of building robots could be used to create new factories in turn.
5. Automation of engineering. The largest fraction of costs in engineering is the human labor required for programming and designing new devices. Automation like CAD simplifies prototypes design.
6. New types of manufacturing. For RoboBee, a new way of creating 3D structures was invented, where 2D sheets are combined into a 3D shape. This has the potential to be a cheap and scalable method of mass manufacturing (Davis, 2013). A related approach is origami robotics (Zhakypov & Paik, 2018).

## 6.4 Economies of scale for drone armies

Projections for 2021 predict 67 million sales of consumer drones with a doubling time of two years (Tractica, 2016). An economy of scale calculator (Repetitive Learning Cost Model And Calculator, 2018) based on (Ostwald, 1992) yields a sevenfold cost reduction with a 1000-fold increase in production. This means that if the cheapest drones now retail for 20 USD, their bulk price is probably less than 10 USD, and a sevenfold reduction in this price will give a cost of around 1.3 USD for drone. Thus, the whole program to build tens of billions of drones will costs around 100 billion USD, within reach of the current military budgets of the superpowers. The estimate doesn’t take into account many factors, like growth in military budgets in response to perceived threats and the growing size of the economy, as well as cost reductions due to automation and miniaturization, so the real price may be even smaller—though unexpected difficulties are also possible.

There is a trend for the size of the smallest robots to continue to shrink. This miniaturization trend will go through several stages before fully autonomous nanorobots appear; the main law of this trend is that smaller size also means an increase in mass production and lower prices.

## 6.5 Drones as a “cryptoweapon” and the unstable nature of a drone arms race

Drones could be used for anonymous or false flag attacks, increasing global instability and the risk of triggering WW3 (Reiger, 2012) (S. Lem, 1986). The slow slope without barriers to larger drone war means that the effects of such attacks could escalate quickly (Tegmark et al., 2018). Drones could be used as instrument for the first disarming strike against a nuclear power. Knowing this, former nuclear superpowers, which were not able to create drone swarms in time, may try act preventively. It is not easy to stop drone war; many actors could continue to produce and use drones during the war.

# 7. Assessment of the global catastrophic risk of military robotics

## 7.1 Future of the military AI

The field of future military AI is much wider than just autonomous weapons, as was shown by (De Spiegeleire, Maas, & Sweijs, 2017). It includes military strategic planning, coordination of all military units, military intelligence, and organization of military manufacturing. These upper levels of military AI will make any army deadlier and more effective, even if it does not consist of drones. Though it may not be intended for military use, any evolving global AI will converge into military AI, as it has to overcome resistance of its potential enemies (Turchin & Denkenberger, 2018b).

Pure cyber weapons will also play a role in military AI, and they may be used to interfere with civilian infrastructure or convert it into weapons. Such interference may include attacks like hacking self-driving cars and home robots.

## 7.2 Comparison with other weapons of mass destruction

Military robotics as a global risk may be insignificant after all if it will be “outperformed” by other, more effective, weapons of mass destruction.

Biological weapons may much cheaper, but they are difficult to control, so superpowers may rely on them to a lesser extent, leaving them as a weapon choice of “existential terrorists” (Torres, 2016), (Turchin et al., 2017). Military robots are needed to search for and control such terrorists, as well as to act in the contaminated areas.

Drone swarms as a global catastrophic weapon could be “outperformed” by swarms of genetically modified flies, able to bite humans with deadly effect, and also able to self-replicate. They could be as small as mosquitos, which already have all needed systems and the “intelligence” to find and attack humans. Some work on cyborgisation of insects as weapons has already been done (jlredford, 2010).

While nuclear weapons seem to be stagnating, future arms race could create new types, like very large gigaton-scale bombs and salted cobalt bombs (Porter, 2018). Advances in laser isotopic separation (Serrato, 2010) or pure fusion (Jones & von Hippel, 1998) could make nuclear bombs much cheaper.

## 7.3 Civilizational collapse or existential risk?

It seems like it is technically possible to create human extinction via drone swarm robotics, but it requires a specific chain of events, like delay in AGI, creation of larger drone stockpiles, and issuance of an accidental command for it to launch an indiscriminate attack on all humans. Such a chain of events may seem more probable based on the considerations relating to arms races, difficulties of defense and price of manufacturing described above, but still is not 100 per cent certainty, and more correct estimation will be 1 percent (or an orange level of risk in the classification of (Turchin & Denkenberger, 2018a)).

A much more probable scenario is one in which drone only contribute to a global catastrophe, where several other factors play roles, like in the case of a world war. It is much more difficult to protect against both drone swarms and biological contamination and use of nuclear-salted weapons would contribute even more to the risk.

If drone swarms are able to reduce global population by a factor of ten, humanity could survive, despite it being a global catastrophe. But drone swarms could be the last straw when combined with other factors to create a complex catastrophe that could kill the last remaining humans—or at least contribute to the start of the demise of technological civilization with the loss of needed technologies. Such civilizational catastrophe could later evolve into full degradation and subsequent extinction.

Lowering the computational complexity of omnicide removes the requirement of superintelligence, and thus, the opposition between drone swarm catastrophe and self-improving AI catastrophe is dissolving. As drone-swarm catastrophe is technologically simpler than superintelligence, it could happen earlier, and even prevent the emergence of superintelligence. Unabomber Ted Kaczynski wrote from jail that the only chance for human survival is a smaller catastrophe which will stop creation even of more advanced technologies (Hanson, 2018). We think that the risks posed by a smaller catastrophe could help humanity to unite and create an effective “global risks prevention committee” at the United Nations.

## 7.4 What can be done?

The campaign to stop killer robot is great initiative and they did a lot of work on promotion the risks of autonomous weapons. Where are several examples where international treaties helped to reduce the risks of biological, chemical and even nuclear weapons, and it all started from the rising awareness about the nature of the risk.

# Conclusion

In this article, I explore the future evolution of the new weapon of mass destruction— swarms of military robots—and explore the question of if they could pose existential risk, or at least global catastrophic risk. We find that existential risk posed by robotic armies alone is possible, but unlikely, as it requires very specific social and technological lines of future development.

But the chances that the military robotics could contribute to a global catastrophe and subsequent civilizational collapse are much larger, if it is one step in a complex catastrophe, e.g. in the case of WW3.

Military robots could be useful to track some other types of catastrophic risks, like targeting potential terrorists working on biological weapons in remote locations. However, the growing social resistance to large military robotic swarms may limit their implementation and become the starting point for international treaty to regulate such activity.

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