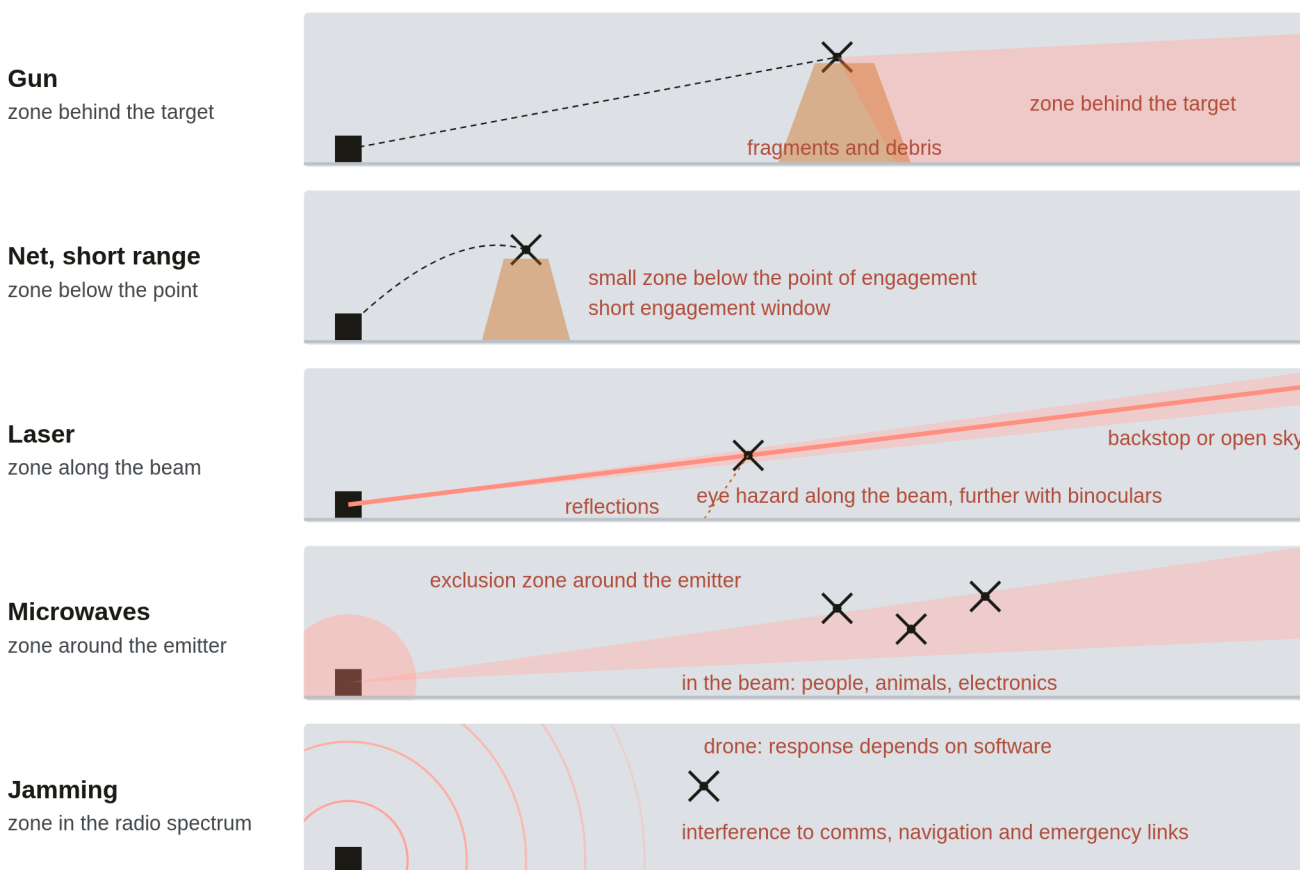


Every method has its zone

MACIEJ M. KASPEREK

Talk about bringing down drones usually ends at range and cost per shot. Yet each method needs a space in which its use is safe, and that space sets its real limits.

Over a military airfield or an empty firing range the choice of counter-drone method is mainly a calculation of effectiveness. Over a refinery, a power plant or a residential district a second question appears, often more important than the first. What happens to the round that misses, the beam that travels on, or the signal that reaches where it should not? Each method answers differently, and each needs a different zone that should hold no people, no aircraft and no sensitive electronics. This piece compares those zones and gives figures only where a manufacturer, a military or a public authority has published them. Where no such figure exists, it says so plainly.



The zones each of the five methods requires, shown schematically and not to scale. The square is the emitter, the cross a drone, the colour a zone that should hold no people.

GUNS: THE ZONE BEHIND THE TARGET

An anti-aircraft gun fires rounds that carry on after a miss and fall far behind the target. Modern programmable ammunition bursts near the drone and throws out a cloud of tungsten sub-projectiles, which raises the chance of a hit. The sub-projectiles and fragments still fall to the ground, and a missed round of

ordinary ammunition travels further still. A zone therefore forms behind and below the target that should be empty or controlled. Over an industrial site that is hard to guarantee. In its submission on the Czech bill, the Confederation of Industry of the Czech Republic called a kinetic shot over an industrial plant extremely dangerous.

The war in Ukraine offers a case study, with German-supplied Gepard and Skynex systems using 35 mm programmable ammunition against Shahed-type drones. The effective range of Skynex is given as about four kilometres, and public estimates of the cost of a single engagement vary several-fold. The estimate attributed to the manufacturer is about four thousand euros. Independent analyses give between several thousand and more than thirty thousand dollars, depending on how many rounds are fired. The size of the zone behind the target for such systems in built-up areas is not published.

NETS AND OTHER SHORT-RANGE SYSTEMS: THE ZONE BELOW THE POINT OF ENGAGEMENT

Net launchers, smooth-bore guns and interceptor drones have a small zone behind the target, because their projectiles are slow and do not travel far. They pay for that with a short engagement window. The target has to be stopped in the last tens or hundreds of metres. The captured or destroyed drone then falls below the point of engagement.

The best-documented example is the British SkyWall100 launcher. The manufacturer gives a range of a hundred metres and a reload time of eight seconds. The projectile releases a net, and a parachute lowers the captured drone to the ground. The projectile parts descend under the parachute even after a miss. The zone below the point of engagement is therefore small and controlled. A drone moving at twenty metres a second covers a hundred metres in five seconds, so there is no time for a second shot.

LASERS: THE ZONE ALONG THE BEAM

A high-energy laser beam that misses travels on until it meets an obstacle. Along that whole path it is a hazard to the eyes. Laser safety measures this as the nominal ocular hazard distance, the distance beyond which exposure no longer exceeds the maximum permissible exposure. For anyone looking through binoculars that distance is greater. A beam reflected off a shiny surface such as a window, a car body or the drone itself creates further hazard zones. Range safety rules therefore require the beam to end on a backstop within a controlled area, with the airspace above it controlled.

The laser also has limits that are not a zone but narrow its use. Analyses by the Congressional Research Service and the US Government Accountability Office note that rain and fog shorten the range and degrade the beam. The laser is therefore not an all-weather weapon. It engages one target at a time, needs several seconds on it and several more to move the beam. Protocol IV to the Convention on Certain Conventional Weapons prohibits lasers designed to cause permanent blindness. For the use of other lasers it obliges states to take all feasible precautions.

A publicly documented example is the British DragonFire laser. According to the UK Ministry of Defence, the energy for one shot costs about ten pounds. The system can hit a one-pound coin from a kilometre away. In trials in 2025 it brought down drones flying at up to 650 kilometres an hour. The nominal ocular hazard distance for such lasers, and their range in poor weather, are not disclosed.

MICROWAVES: THE ZONE AROUND THE EMITTER

A high-power microwave weapon does not aim at a single point. It illuminates a slice of space and disrupts or damages the electronics of everything within it. That is its greatest strength, because it works on many targets at once. It is also its greatest limit. The Government Accountability Office notes that a wide-beam weapon affects every device in the area, friendly and hostile alike. Around the emitter and along the beam an exclusion zone is therefore needed for people, animals and electronics, including electronics belonging to the site's neighbours.

A microwave weapon can work in two modes that differ in their zone. Disrupting a drone's electronics needs a weaker field, and burning them out permanently a field orders of magnitude stronger. The disrupting mode can work at intensities not far from those permitted for people, so its zone is small. The destroying mode needs a far larger zone.

Health protection limits show where that zone comes from. For frequencies from 2 to 300 GHz the ICNIRP 2020 guidelines and the Polish 2019 regulation set 10 W/m² for the general public. The ICNIRP guidelines allow 50 W/m² for occupationally exposed people, and both values are time-averaged. For short pulses Polish rules allow a peak power density of up to a thousand times the reference level. These limits guard against tissue heating and are written for people, and an animal in the beam is subject to the same mechanism. In the destroying mode the intensity in the beam exceeds these limits many times over.

Microwaves penetrate deep into the body and can heat tissue before the heat receptors in the skin respond. Local hot spots can damage internal tissue, and metal implants and implanted devices such as pacemakers can intensify them. The effect depends on intensity and exposure time. Over civilian ground the collateral risk of the destroying mode is too great. A zone is therefore needed that people may not enter, with procedures that cut the emission when someone appears in it.

The case study is the American Leonidas system, whose manufacturer published trial results from August 2025. According to them the system disabled all sixty-one drones, including a swarm of forty-nine with a single pulse. The manufacturer did not give the range, saying only that the new version has more than twice the range of the 2022 version. The radius of the exclusion zone for people is likewise not published.

JAMMING: THE ZONE IN THE RADIO SPECTRUM

Jamming has no zone behind the target and no zone along a beam in the ordinary sense. It has instead a zone in the radio spectrum, in which it disrupts things it should not. The explanatory memorandum to the Czech bill warns that careless jamming can paralyse mobile networks, emergency-service systems and systems that rely on satellite navigation. The Czech bill therefore does not lift the standing ban on jamming. Poland has allowed it since July 2026, but under conditions. The operator must first declare the equipment with its frequencies, power, antenna positions and sectors, and then report each use. The interior minister or the defence minister may order it stopped. The Czech telecoms regulator noted in the consultation that jamming does not work against fibre-guided drones, autonomous drones or drones with inertial navigation. What happens to a jammed drone depends on its software, so the zone below it cannot be set in advance.

COMPARISON

METHOD	ZONE BEHIND TARGET	ZONE AROUND EMITTER	AIRSPACE OR RADIO SPECTRUM	ZONE BELOW POINT OF ENGAGEMENT	TARGETS AT ONCE	PUBLICLY DOCUMENTED EXAMPLE
Gun with programmable ammunition	yes, large	no	airspace control	yes, fragments and debris	in bursts, one after another	Skynex, range about 4 km, engagement cost estimated from about EUR 4,000 to over USD 30,000
Nets and other short-range systems	small	no	local	yes, small and controlled	one, then reload	SkyWall100, range 100 m, reload 8 s
High-energy laser	yes, the beam travels on	no	yes, hazard to eyes and aircraft	yes, debris	one, several seconds per target	DragonFire, about GBP 10 of energy per shot
High-power microwaves	along the beam	yes, people, animals, electronics	yes	yes, debris	many at once	Leonidas, 61 of 61 drones, range undisclosed
Jamming	no	yes, in the radio spectrum	yes, communications and navigation	depends on the drone's response	many, if they respond to the interference	Poland, duty to declare equipment and each use

RANGE IS HALF THE QUESTION

None of these methods is best regardless of place. The gun reaches far but needs emptiness behind the target. The laser is cheap to fire but needs clear air and a backstop to end the beam. Microwaves take down a swarm but need a zone free of people and of other parties' electronics. Short-range systems have the smallest zones but leave the least time. Jamming destroys nothing yet disrupts everything around it and does not work on drones that listen for nothing.

In a city and in an explosive atmosphere the question of the zone is therefore as important as the question of range. The Czech bill requires the operator to carry out a risk assessment. The zones described above are a natural part of such an assessment, whichever method the operator chooses.

Declaration of interest. The author is the founder of Silesian Advanced Systems, a team developing an autonomous counter-drone system and preparing to incorporate a company. The system belongs to the family of short-range kinetic means, so the author has a commercial interest in the subject. All figures on systems and limits come from the open sources listed below.

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