DISCUSSION PAPER | NOV 2018

Article36

Acoustic Weapons

Discussion paper for the Convention on Certain Conventional Weapons (CCW)

Geneva, November 2018*

Article 36 is a UK-based not-for-profit organisation working to promote public scrutiny over the development and use of weapons.

www.article36.org
info@article36.org
@Article36

Acoustic (or sonic) weapons are under research and development in a few countries and have been the subject of interest and much speculation for several decades.[1] Such devices have repeatedly captured the interest of the press, most recently when it was reported in 2016 that several staff members at the American embassy in Cuba were allegedly 'subjected to an "acoustic attack" using sonic devices' that caused serious health problems.[2] Neurologists and engineers have challenged this claim.[3]

Acoustic weapons aim to use the propagation of sound – a variation in pressure that travels through a fluid medium (such as air) to affect a target. Most of the acoustic weapons that have been speculated upon are based on either ultrasound (above 20 kilohertz, kHz), low frequencies (below 100 hertz, Hz) or infrasound (below 20 Hz) deployed at high levels.[4] The human range of hearing is commonly given as between 20 Hz and 20 kHz. In reality, the upper hearing-threshold frequency decreases significantly with age, whereas sounds with lower frequencies can be heard and otherwise perceived if the level is high enough.[5]

Although a few acoustic devices exist today that could be used as weapons, and sound is implicated in the use of force in the military and law enforcement domains in various ways, the potential for weaponization of acoustic devices has likely been overstated.[6] Recent scientific analyses have debunked myths and disproven earlier claims about the effects of acoustic devices on humans and have drawn attention to the practical limitations of such technologies.[7]

Nevertheless, consideration of acoustic weapons brings to the fore a number of issues that deserve attention from the perspective of multilateral weapons control, including within the framework of the Convention on Certain Conventional Weapons (CCW):

- Often branded as 'non-lethal' or 'less lethal',[8] acoustic devices are open to the same questions and criticisms levelled against other technologies given that label (including that they may undermine boundaries distinguishing acceptable modalities of force in war-fighting and in law enforcement, and that their use in conjunction with kinetic weapons actually increases the risk of death).
- Acoustic weapons raise questions of delineation between devices specifically designed to harm through acoustic phenomena like sound or vibration (acoustic weapons properly speaking), other weapons with harmful acoustic effects (such as explosive weapons) and the use of organized sound (music) or unorganized sound (noise) by militaries and police, including to torture or terrorize. Such delineation in turn has consequences for national and international control and raises further questions about the role of international regulation.
- Consideration of acoustic weapons raises the question of our orientation towards technologies that target the human senses ('sensory violence'). Parallels that could be drawn from the prohibition on blinding laser weapons (formalized in CCW Protocol IV) and the opprobrium attached to blinding as a method of warfare deserve further exploration in light of the evolving understanding of deafness and blindness from a health perspective.
- Consideration should be given to the ethical, health, legal and environmental concerns about the acceptability and desirability of acoustic violence – sound as a technique of authority and control[9] – especially in frequencies beyond the human audible range,[10]

* This paper was written by Maya Brehm and Anna de Courcy Wheeler. The bulletin was updated on 3 December 2018 to note the position of Cuba in footnote 2.

and the expansion of weaponized sound into civilian spheres. As with directed energy weapons, some acoustic weapons may raise questions about systems where the source of harm is not identifiable or comprehensible to those experiencing it.

- Given the well-documented health impacts of weapon noise on humans, consideration of acoustic devices also raises the question of whether political measures should be taken at the international level to better protect both civilians and soldiers from weapons that cause noise-induced hearing loss.
- Finally, there is concern that a lack of reliable, scientifically sound and peer-reviewed data on the specifications and effects of acoustic devices[11] has in the past driven research and development (including animal testing) into acoustic weapons in expectation of unrealistic potential. This has contributed to speculations and public anxiety about acoustic, especially infrasound, weapons.

Current state of play

The fascination that acoustic weapons prompt among certain militaries, police forces, journalists, scientists and publics has to be understood against the backdrop of a complex and long-standing relationship between sound, war and violence.[12] What accounts of such diverse phenomena as the Nazi-German 'Windkanone', Soviet 'psychocorrection methods', the US 'Urban Funk Campaign', the British 'Curdler' and the use of sound to torture,[13] harass, intimidate or terrorize[14] have in common is a long-standing belief (justified or not) in the destructive power of sound and vibration. This belief and the search for bloodless, so-called 'non-lethal' technologies of violence, which intensified from the early 1990s, have driven some states, mainly the US, to push research and development into acoustic weapons, especially in the infra- and ultrasonic frequency ranges.

Decades of research and development and considerable hype notwithstanding, the potential for weaponization of acoustic devices has likely been overstated.[15] Inherent difficulties in projecting sound energy to tactical ranges, as well as limited human effects in practice,[16] have hampered the attempts of states and scientists to produce an acoustic-based weapon that can be fully operationalized. Low frequency and infrasound can travel over considerably larger distances than higher-frequency sound and are hardly attenuated through dissipation.[17] However, at low frequency, sound cannot be projected in a directed beam; at higher frequency, it can. But if high-frequency sound waves are to have an impact on humans, the sound pressure would need to reach such a level that the sound waves become deformed.[18] In order to produce such effects, the sound source with its auxiliary equipment would be of a weight and dimension that could not easily be carried by a single person, limiting practical military and law enforcement applications.[19]

Certain types of acoustic devices currently reported to be in use by law enforcement or military actors have drawn particular attention – and criticism – and raise questions that are of interest from the perspective of multilateral weapons control more broadly. These include acoustic hailing devices, flash-bang devices, and high-frequency devices, all briefly described below.

Acoustic hailing devices (AHD) or 'sound cannons'

AHD operate in the audible range and issue high-energy acoustic beams to communicate with, warn and potentially disorient or disable a person. A number of states have developed and are using such systems,[20] in both military and law enforcement settings, primarily in connection with crowd and border control. Such devices can reportedly produce 'harmful, pain-inducing tones' over some distance,[21] and can damage the human ear and even cause permanent hearing loss over short distances.

The best-known of these devices is the Long Range Acoustic Device (LRAD). It resembles a flat loudspeaker that uses many piezoelectric transducers, set in a staggered arrangement.[22] The LRAD was developed as a military tool to enforce exclusion zones around naval vessels following an attack on the navy warship USS Cole in Yemen in 2000. It has subsequently been used by the US navy to protect shipping lanes around the Iraqi port of Basra and nearby oil terminals.[23] It has also reportedly been used for 'hailing and warning' by cruise and transport liners to deter pirates,[24] been deployed by police forces in several countries[25] and is being attached to drones.[26]

The LRAD has relatively high directivity (with a beam opening angle of 5–15 degrees) and transmits mainly high frequencies (above 1 kHz). The LRAD 1000 projects voice messages to a range above 500 m, and warning tones to above 1000 m.[27] Various, scaled-down and scaled-up versions are available.[28]

There are also reports that similar devices, termed 'sonic blasters', have been used to produce a series of high-intensity blasts (high levels of sound pressure and volume) to affect a target rather than to communicate. Among the most reported examples are Israel's sonic pulser, 'The Scream',[29] and its 'Thunder Generator', originally developed as 'an environmentally friendly soil-disinfection machine' to scare away birds from crops, and later used for riot control.[30]

Flash-bang devices

Flash-bang devices (or 'noise flash diversionary devices') contain mixtures of fast-burning propellants and pyrotechnics to produce a loud 'bang' and a bright flash of light. They often take the form of grenades ('stun grenades', 'flash-bang grenades', 'sound bombs') that are deployed by hand or from shotgun cartridges.[31]

Flash-bang grenades are in widespread use by military and law enforcement actors and are designed to temporarily blind, disorient and cause dizziness. As the casing is not intended to produce fragmentation during detonation, such flash-bang devices are typically labelled 'non-lethal'. There are, however, several known cases of serious injury and death resulting from their use.[32]

A US performance characterization study of selected flash-bang devices noted that one of the concerns associated with their use 'is the high level of sound generated by them, with respect to hearing impairment or damage'.[33] All of the devices tested in the study exceeded the US Department of Defense's 140 decibel (dB) threshold requirement for use of hearing protection. According to one source, the 'threshold noise' of a flash-bang device 'can reach 180 dB in

closed spaces, where the effects of the acoustic signature can be compounded'.[34] This is comparable to the peak levels of heavy artillery (measured at the shooter's position close to the gun).[35]

High-frequency devices

The particularity of high-frequency devices is that they emit a sound at a frequency on the border of being ultrasonic, which is intended to be heard only by younger people, whose ears tend to be more sensitive to sound at high frequency compared to most older people.

The best-known model is the 'Mosquito Teenager Deterrent/Anti-Loitering Device'. This was initially developed to disperse vermin and is now primarily marketed to private persons and businesses 'for dispersing groups of misbehaving teenagers'.[36] According to the manufacturer, the Mosquito MK4 can be set to emit a sound at 17 kHz that only people under 25 can hear or at 8 kHz, audible to people of any age, with four volume/distance settings and a maximum volume of 103 dB.[37]

Adverse effects and risks

Acoustic devices can produce a range of harmful effects, most notably temporary and permanent hearing loss, as well as pain, disorientation, sensations of discomfort and nausea.[38] Importantly, the physiological and psychological effects of sound on humans depend not only on frequency, but also on sound pressure levels, duration and number of exposures and recovery time between exposures.[39] And, effects vary significantly from one individual to another.

At 120 dB, where discomfort typically begins, there is a high risk of hearing loss even for short and few exposures. Lasting damage to the ear can occur at levels below the threshold for ear pain, which sets in at between 135 and 162 dB depending on frequency.[40] At extreme levels, physical damage to organs of the ear can occur even with short exposure.[41] At about 160 dB, sound in the audio region causes eardrum rupture. Infrasound at high levels can produce aural pain and damage, a sensation of pressure in the middle ear and annoyance, but it does not have the profound effects often associated with it.[42] Ultrasound at extreme levels (close to 160 dB) was reported to produce a slight heating effect that could be felt on the skin.[43]

As with other technologies labelled 'non-lethal', the use of acoustic devices has attracted strong criticisms from humanitarian, health and human rights perspectives. In a war-fighting context, concern has been raised that when an acoustic device is 'used in a pre-lethal way to incapacitate before killing' it actually increases the 'killing power of lethal force' rather than reducing casualties.[44] Critics also object to the extension of weaponized sound to (domestic) law enforcement and the associated blurring of the boundaries of acceptable ways of applying force. In a number of concrete situations, users were considered to have taken insufficient care to protect the lives and health of people within the range of acoustic devices, and to account for the specifics of a situation and individual differences in susceptibility to injury and trauma.[45]

More generally, critics complain of a lack of proper documentation regarding effects at various frequencies and levels in actual-use situations, as well as a lack of analyses by independent bodies. This is not only a humanitarian concern, but it also challenges democratic control over the use of force and enables misconceptions and speculations to endure about the effects of acoustic devices, justifying the allocation of funds for further research and development, with potentially negative consequences for international and human security.

Governance and regulation

'Acoustic weapons' or 'acoustic devices' are not authoritatively defined or regulated in international law, nor are they the subject of dedicated multilateral policy discussions.[46] The potential to use acoustic devices to communicate or warn, as well as to compel, intimidate or injure, for domestic law enforcement and military purposes (as well as by private citizens), has sparked debate in legal quarters about how such devices, in particular the LRAD, should be properly categorized. Some argue that they are hailing devices that should neither be subject to national weapons reviews, including those warranted by Article 36 of 1977 Additional Protocol I,[47] nor to export controls applicable to weapons.[48] Others have taken the opposite view.[49] A NATO study, for instance, describes 'acoustic devices' as '[w]eapons utilizing acoustic energy to induce human effects through the sense of hearing or through the direct impact of pressure waves on other parts of the human body'.[50]

The question of categorization aside, a number of existing regulatory frameworks constrain the use of sound in connection with the use of force, notably international humanitarian law (IHL) and international human rights law (IHRL), as well as national health and safety standards. In relation to the conduct of hostilities, the question is often asked whether the use of acoustic devices would comply with the IHL prohibition on the use of weapons and methods of warfare of a nature to cause superfluous injury or unnecessary suffering.[51] The US, for example, has determined that the LRAD does not violate that legal threshold, 'because the discomfort is well short of permanent damage to the ear'.[52] An earlier preliminary assessment by the US Navy had concluded that even 'aural systems that could cause permanent hearing loss' would not be illegal.[53] At the international level, the debate is complicated by divergent interpretations of the rule on superfluous injury and continued disagreement about the (il-)legality of blinding (and thus, by analogy, deafening) as a method of warfare.

In this connection, it is sometimes proposed that a prohibition on acoustic weapons could be derived, by analogy, from the prohibition on blinding laser weapons,[54] another 'non-lethal' technology that targets the human senses. This argument has been rejected on the grounds that 'the eye provides 90% of sensory input, the ear accordingly provides much less. Moreover, permanent hearing loss is not necessarily complete loss and prolonged hearing loss means that such loss is only temporary'.[55] Such a statement betrays a common bias that ranks vision over other senses (ocularcentrism)[56] and fails to take account of evolving understandings of deafness (and blindness) from medical and public health perspectives. It also speaks to a lack of in-depth and critical consideration of sound and the 'acoustic authority' of the state (the 'politics of frequency and amplitude')[57] in contemporary legal thought.[58]

Legal commentators have further pointed to the great potential for indiscriminate effects from the use of acoustic devices, which may violate the IHL rule on distinction and the prohibition of indiscriminate attacks.[59] Testing has shown that the LRAD, for example, does

not only affect those targeted by the device but also bystanders in the directional periphery.[60] Especially at longer ranges, questions arise regarding the controllability of the propagation of sound, as 'the transmission direction will be deflected in case of strong winds'[61] or reflected off surfaces in built-up environments.[62]

The 'indiscriminateness' of acoustic devices is also a major human rights concern. Pertinent international standards on the use of force in law enforcement operations require that 'the development and deployment of non-lethal incapacitating weapons should be carefully evaluated in order to minimize the risk of endangering uninvolved persons, and the use of such weapons should be carefully controlled.'[63] In several cases, legal challenges have been brought over injuries caused by the use of flash-bang devices in law enforcement situations[64] – use that raises questions concerning the rights to life or health, and freedom of peaceful assembly and movement where the devices were used for crowd control.[65]

Moreover, acoustic devices that target the hearing of a group of people on the basis of their age, as does the Mosquito, raise issues regarding the right to equality and non-discrimination and from a child rights perspective.[66] The device has been declared illegal in some jurisdictions.[67] Devices that are inaudible (to adults) also raise a rule of law concern as affected populations may face formidable challenges in accessing an effective remedy.[68] Finally, it bears restating that both IHL and IHRL prohibit the use of sound and acoustic devices to terrorize, torture or inflict inhuman or degrading treatment.[69]

In terms of governance and regulation, acoustic devices raise the question of what constitutes an acceptable health risk and what the standard of reference should be given their diverse applications in military, law enforcement and private settings. In the military, where noise exposure is a well-known problem, a number of impulse-noise exposure criteria have been developed.[70] 'Safe exposure' to *impulse* noise is sometimes given as a peak level of 162 dB,[71] but a 2003 NATO research study was unable to propose a single measure or assessment method to predict the auditory hazard for different impulse noises and blasts.[72]

In relation to *continuous* sound, the World Health Organization considers that exposure levels above 85 dB in an occupational setting are 'hazardous for workers',[73] and deems exposure to recreational sound in excess of 85 dB for eight hours or 100 dB for 15 minutes 'unsafe'.[74] Although these standards aim to protect workers from damage over years of exposure, in a Canadian case implicating an LRAD, the judge considered that occupational health and safety legislation served as a useful guide to determine restrictions on the use of LRAD to prevent unsafe exposure which would amount to human rights violations.[75] In 2011, Canadian authorities defined minimum distances at various levels for 'urban scenarios', and recommended that the use of the alert function (i.e. use to emit a high-decibel, narrow-frequency sound wave rather than use as a powerful loudspeaker) 'should be minimized', that the devices 'should not be operated continuously' and that any use should be followed by an equivalent period of silence.[76]

In the same vein, Jürgen Altmann has proposed rules for safe operation to prevent injury. He suggests technical measures to limit the sound power of LRAD as a function of distance between the device and the exposed population, and to limit the duration of use, as well as a ban on particular types (such as certain mobile LRAD) and a requirement to document any use of a device automatically.[77] Taking a precautionary orientation, Amnesty International and Omega Research Foundation recommend that the use of acoustic devices in the alert function be suspended 'until an independent body of medical, scientific, legal and other experts has subjected the effects and potential uses of the type of device in question to rigorous assessment and can then demonstrate a legitimate and safe use of the device for law enforcement subject to specific operational rules consistent with human rights standards.'[78]

Measures on acoustic weapons at the national and international levels can build on a rich literature on non-lethal weapons in the use of force, including detailed recommendations on selection, testing, deployment, operational procedures, training, monitoring and accountability, for multilateral controls as well as specific legal instruments.[79]

END NOTES

1 See, e.g., N. Broner, 'The Effects of Low Frequency Noise on People – A Review', 58(4) *Journal of Sound and Vibration* (1978), https://waubrafoundation.org.au/resources/broner-n-effects-low-frequency-noise-people-review/. The work of Vladimir Gavreau is often cited in this context (see, e.g., G. Vassilatos, 'The Sonic Doom of Vladimir Gavreau', 52(4) *Borderlands* (1996), https://borderlandsciences.org/journal/vol/52/n04/Vassilatos_on_Vladimir_Gavreau.html). His work has more recently been described as 'unscientific' (J. H. Mühlhans, 'Low Frequency and Infrasound: A Critical Review of the Myths, Misbeliefs and Their Relevance to Music Perception Research', 21(3) *Musicae Scientiae* (September 2017) 272).

2 E. Labott et al, 'US Embassy Employees in Cuba Possibly Subject to "Acoustic Attack"', CNN, 10 August 2017, https://edition.cnn.com/2017/08/09/politics/us-cuba-acoustic-attack-embassy/index.html. Cuba has denied any involvement, see E. McKirdy et al, 'Cuban president denies "sonic" attacks on US diplomats', CNN, 17 September 2018, https://edition.cnn.com/2018/09/17/americas/cuba-sonic-attack-miguel-diaz-canal-denial-intl/index.html.

3 E.g. R. E. Bartholomew, 'Politics, Scapegoating and Mass Psychogenic Illness: Claims of an "Acoustical Attack" in Cuba are Unsound', 110(12) *Journal of the Royal Society of Medicine* (2017); C. C. Muth and S. L. Lewis, 'Neurological Symptoms Among US Diplomats in Cuba', 319(11) JAMA (20 March 2018). Researchers who reverse-engineered a recording of what embassy staff heard concluded, however, that '[i]f ultra-sound is to blame, then a likely cause was two ultra-sonic signals that accidentally interfered with each other, creating an audible side effect' (J. Kumagai, 'Reverse Engineering the "Sonic Weapon"', 55(3) *IEEE Spectrum* (March 2018), https://ieeexplore.ieee.org/abstract/document/8302371). See also I. Sample, 'Cuban "Acoustic Attack" Report on US Diplomats Flawed, Say Neurologists', *The Guardian*, 14 August 2018, https://www.theguardian.com/world/2018/aug/14/cuban-acoustic-attack-report-on-us-diplomats-flawed-say-neurologists.

4 N. Davison, *'Non-Lethal' Weapons*, Palgrave Macmillan, 2009, p. 186.

5 J. Altmann, 'Acoustic Weapons – A Prospective Assessment', 9(3) *Science & Global Security* (2001) 173, scienceandglobalsecurity.org/archive/sgs09altmann.pdf; Mühlhans, 'Low Frequency and Infrasound', 270.

6 A NATO study notes: 'A large variety of acoustic devices have been proposed for non-lethal applications. Most are of uncertain effectiveness and many could damage hearing.' (North Atlantic Treaty Organization, *The Human Effects of Non-Lethal Technologies*, RTO Technical Report, NATO doc AC/323(HFM-073)TP/65, August 2006, p. G-4, https://www.sto.nato.int/publications/STO%20Technical%20Reports/RTO-TR-HFM-073/$$TR-HFM-073-ALL.pdf.). See also J. R. Jauchem and M. C. Cook, 'High-Intensity Acoustics for Military Nonlethal Applications: A Lack of Useful Systems', 172(2) *Military Medicine* (2007) 186, https://academic.oup.com/milmed/article/172/2/182/4578046.

7 See in particular Altmann, 'Acoustic Weapons'; Mühlhans, 'Low Frequency and Infrasound'.

8 See in particular D. P. Fidler, 'The Meaning of Moscow: "Non-Lethal" Weapons and International Law in the Early 21st Century', 87(859) *International Review of*

the Red Cross (September 2005), https://www.icrc.org/eng/assets/files/other/irrc_859_fidler.pdf; N. Lewer and N. Davison, *Bradford Non-Lethal Weapons Research Project* (BNLWRP), *Research Report no. 7*, May 2005, https://bradscholars.brad.ac.uk/handle/10454/3999.

9 J. E. K. Parker, 'Towards an Acoustic Jurisprudence: Law and the Long Range Acoustic Device', 14(2) *Law, Culture and the Humanities* (2018) 209.

10 Steve Goodman speaks of a 'creeping colonization of the not yet audible and the infra- and ultrasonic dimensions of unsound' (S. Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear*, The MIT Press, 2010, p. xvi) and Juliette Volcler cites SPIRAW's 'recherche des frontières que colonisent tranquillement les militaires et les forces de police à travers l'usage d'armes soniques' (J. Volcler, 'Le son comme arme', *Article XI*, February 2010, revised January 2011, https://www.article11.info/spip/IMG/pdf/v2_le_son_comme_arme.pdf).

11 Most of the information about such devices comes from the US, which has publicly reported more on its research and development in this area than most other states.

12 For an in-depth treatment of this issue, see Goodman, *Sonic Warfare*; J. M. Daughtry, *Listening to War: Sound, Music, Trauma, and Survival in Wartime Iraq*, Oxford University Press, 2015; N. Ramsey, 'Listening to War: Sound and Noise in Romantic Era Military Writing', 5(2) *Republics of Letters* (2017), https://arcade.stanford.edu/sites/default/files/article_pdfs/RofL_v06i01_Ramsey_03Pass.pdf.

13 See in particular S. G. Cusick, 'Music as Torture / Music as Weapon', *Revista Transcultural de Música* (2006), https://www.sibetrans.com/trans/articulo/152/music-as-torture-music-as-weapon.

14 Well-documented instances include American troops blasting the Vatican's embassy in Panama City to dislodge Noriega in 1990 (A. Campoy, 'The US Pursuit of Panama's Manuel Noriega Kicked Off a New Era of Music Torture', *Quartz*, 30 May 2017, https://qz.com/994372/manuel-noriegas-capture-in-panama-kicked-off-a-new-era-of-sound-as-psychological-warfare/); the FBI's sonic assault in Waco in 1993 (V. Madsen, '*Cantata of Fire: Son et Lumière* in Waco Texas, Auscultation for a Shadow Play', 14(1) *Organized Sound* (2009)); the sonic booms of Israeli fighter jets flying at low altitude over Palestinian cities in 2005 (C. McGreal, 'Palestinians Hit by Sonic Boom Air Raids', *The Guardian*, 3 November 2005, https://www.theguardian.com/world/2005/nov/03/israel); US jets over Nicaraguan cities in 1984 (International Court of Justice, *Military and Paramilitary Activities in and Against Nicaragua* (*Nicaragua v United States of America*), Judgment (Merits), 27 June 1986, §§87, 91) and the blasting of music during the US siege of Falluja in 2004 (J. Pieslak, *Sound Targets: American Soldiers and Music in the Iraq War*, Indiana University Press, 2009, p. 84). For more information on these phenomena, see Volcler, 'Le son comme arme'; Cusick, 'Music as Torture / Music as Weapon', Daughtry, *Listening to War*, Goodman, *Sonic Warfare*.

15 Davison, *'Non-Lethal' Weapons*, p. 186.

16 See J. Altmann, *Millimetre Waves, Lasers, Acoustics for Non-Lethal Weapons? Physics Analyses and Inferences*, Deutsche Stiftung Friedensforschung, 2008, p. 44, https://www.ssoar.info/ssoar/handle/document/26039 (noting that 'after almost ten years of research, the [US Joint Non-Lethal Weapons Program] stopped funding infrasound-weapon work for lack of "a reliable, repeatable bio-effect with sufficiently high infrasound amplitude at a minimum specified range"') and Jauchem and Cook, 'High-Intensity Acoustics for Military Nonlethal Applications', 186 (concluding that '[o]n the basis of results of numerous investigators, it seems unlikely that high-intensity acoustic energy in the audible, infrasonic, or low-frequency ranges will provide a device suitable to be used as a nonlethal weapon').

17 Mühlhans, 'Low Frequency and Infrasound', 269.

18 Altmann, 'Acoustic Weapons', 165.

19 The size and mass differ between infra- and ultrasound devices, but hand-held acoustic weapons of pistol or rifle sizes with a range of tens of metres are highly unlikely according to Altmann (Ibid., 199–200, 204).

20 Altmann, *Millimetre Waves, Lasers, Acoustics for Non-Lethal Weapons?*, p. 6.

21 E. Durr, 'Training with High-Tech Hailer System on the Hudson', *Guard Times* (Spring 2015), 43, https://issuu.com/nynationalguard/docs/gt_spring_15_1_.

22 N. Lewer and N. Davison, 'Non-Lethal Technologies – An Overview', 1 *Disarmament Forum* (2005) 41, https://www.peacepalacelibrary.nl/ebooks/files/UNIDIR_pdf-art2217.pdf.

23 Business Wire, 'American Technology Reports on Growing Long Range Acoustic Devices – LRAD – Business', 26 August 2004, https://www.businesswire.com/news/home/20040826005135/en/American-Technology-Reports-Growing-Long-Range-Acoustic. Its precursors were, however, initially envisaged for civilian markets, unrelated to the use of force. For more information, see Parker, 'Towards an Acoustic Jurisprudence', 210–211.

24 A. Blenford, 'Cruise Lines Turn to Sonic Weapon', *BBC News*, 8 November 2005, http://news.bbc.co.uk/2/hi/africa/4418748.stm.

25 See, e.g., ACLU Pennsylvania, 'City of Pittsburgh Settles G-20 Lawsuits', 14 November 2012.

26 Parker, 'Towards an Acoustic Jurisprudence', 214, https://www.aclupa.org/news/2012/11/14/city-pittsburgh-settles-g-20-lawsuits.

27 Altmann, *Millimetre Waves, Lasers, Acoustics for Non-Lethal Weapons?*, p. 6.

28 See the manufacturer's website: https://www.lradx.com/products/.

29 Y. Katz, 'Kalandiya: IDF Uses "Scream" Anti-Riot Device for 1st Time', *Jerusalem Post*, 22 September 2011, www.jpost.com/Defense/Kalandiya-IDF-uses-Scream-anti-riot-device-for-1st-time.

30 PDT Agro Ltd 'Bird Control Solution', http://pdtagro.com/; D. Hambling, 'A Sonic Blaster So Loud, It Could Be Deadly', *Wired*, 18 January 2010, https://www.wired.com/2010/01/a-sonic-blaster-so-loud-it-could-be-deadly/#more-21519.

31 E.g. Amtech Less Lethal Systems, 'ALS1208 Bore Thunder Muzzle Bang', https://www.lesslethal.com/products/12-gauge/als1208-detail; Defense Technology, '12-Gauge Aerial Warning / Signaling Munition, 100 Meters', http://www.defense-technology.com/products-1/12-gauge-aerial-warning-signaling-munition-100-meters-1154107.html#start=1.

32 For example, in 2014, a French protester died after being hit in the back by a stun grenade ('Sivens: des traces d'explosifs retrouvés sur les vêtements de Rémi Fraisse', *L'OBS*, 28 October 2014, https://www.nouvelobs.com/societe/20141028.OBS3407/sivens-des-traces-d-explosifs-retrouves-sur-les-vetements-de-remi-fraisse.html). The use of these grenades was suspended shortly after the incident, and then prohibited in 2017 ('Plus de deux ans après la mort de Rémi Fraisse, les grenades offensives de type F1 interdites', *Le Monde/AFP*, 12 May 2017, https://www.lemonde.fr/police-justice/article/2017/05/12/plus-de-deux-ans-apres-la-mort-de-remi-fraisse-les-grenades-offensives-de-type-f1-interdites_5126979_1653578.html). See also J. Angwin and A. Nehring, 'Hotter Than Lava', *ProPublica*, 12 January 2015, https://www.propublica.org/article/flashbangs; J. Volcler, *Extremely Loud: Sound as a Weapon*, The New Press, 2013, pp. 59–61.

33 E-LABS Inc., Performance Characterization Study: Noise Flash Diversionary Devices (NFDDs), Final Report, December 2003, p. 5, https://www.ncjrs.gov/pdffiles1/nij/grants/205642.pdf.

34 D. Whitson and J. Clark, 'Flash/Sound Diversionary Devices: A Comprehensive Review', *The Tactical Edge* (Summer 2011) 18, https://www.combinedsystems.com/userfiles/pdfs/Whitson_SU_2011_1.pdf. See also W. A. Burgei et al, 'Developing Non-Lethal Weapons: The Human Effects Characterisation Process', *Defense AT&L* (May-June 2015) 30-34, www.dtic.mil/dtic/tr/fulltext/u2/1015792.pdf.

35 E.g. A. Nakashima and R. Farinaccio, 'Review of Weapon Noise Measurement and Damage Risk Criteria:
Considerations for Auditory Protection and Performance', 180(4) *Military Medicine* (2015) 402.

36 Compound Security Systems, 'Anti-Loitering Devices', https://www.compoundsecurity.co.uk/security-equipment/mosquito-mk4-anti-loitering-device.

37 Compound Security Systems, 'Mosquito MK4 (Anti-Loitering Device): Customise Your Own Kit', https://www.compoundsecurity.co.uk/security-equipment-mosquito-mk4-anti-loitering-device.

38 For a recent study on physical and psychological effects of sound, see J. P. Cowan, *The Effects of Sound on People*, Wiley, 2016.

39 Davison, 'Non-Lethal' Weapons, p. 186. Mühlhans notes that in relation to low frequency, including infrasound, 'the effects depend [...] heavily on sound-pressure levels and considerably less on frequency or the nature of sound.' (Mühlhans, 'Low Frequency and Infrasound', 268).

40 Altmann, 'Acoustic Weapons', 177.

41 Ibid., 174.

42 Davison, *'Non-Lethal' Weapons*, p. 186. See also Mühlhans, 'Low Frequency and Infrasound', debunking several myths about infrasound.

43 Altmann, 'Acoustic Weapons', 186.

44 Davison, *Bradford Non-Lethal Weapons Research Project* (BNLWRP), *Research Report no. 7*, p. 34.

45 For example, during the FBI's Waco siege, it exposed 25 children, many of them toddlers and infants, to the same sound campaign as adults. See, e.g., A. A. Stone et al, 'Report and Recommendations Concerning the Handling of Incidents Such as the Branch Davidian Standoff in Waco Texas', Submission to Deputy Attorney General Philip Heymann, 10 November 1993, Frontline, Waco: The Inside Story, https://www.pbs.org/wgbh/pages/frontline/waco/stonerpt.html.

46 Consider, however, Working Paper COLU/202 on fuel-air explosives, submitted by Sweden in the 1970s, which proposed to prohibit 'the anti-personnel use of weapons which for their effects rely exclusively on shock waves in the air'. When confronted with the criticism that this formulation would capture weapons other than fuel-air explosives, 'e.g. concussion grenades', the sponsor of the proposal responded that 'there were advantages in the use of forward-looking wording' (ICRC, *Conference of Government Experts on the Use of Certain Conventional Weapons (Second Session – Lugano 28.1.-26.2.1976)*, Report, Geneva, 1976, §75).

47 See, e.g., J. Schrantz, 'The Long Range Acoustic Device: Don't Call It a Weapon – Them's Fightin' Words', *Army Lawyer* (August 2010) 53–59, https://www.loc.gov/rr/frd/Military_Law/AL-2010.html; LRAD, 'Fact Sheet', https://www.lradx.com/about/lrad-public-safety-applications-fact-sheet/.

48 The US LRAD was reportedly exported to China (D. Hambling, 'US "Sonic Blasters" Sold to China', *Wired*, 15 May 2008, https://www.wired.com/2008/05/

us-sonic-blaste/). On export control questions, see also Omega Research Foundation and Amnesty International USA, *Submission in Response to BIS Request for Public Comments on Crime Control License Requirements in EAR*, 17 June 2008, pp. 7–8, https://omegaresearchfoundation.org/sites/default/files/uploads/Publications/090000648062f0f5.pdf.

49 Altmann, citing R. Sævik, notes that the Norwegian military call it a weapon (Altmann, *Millimetre Waves, Lasers, Acoustics for Non-Lethal Weapons?*, p. 44). Consider also a recent US ruling finding that the New York City Police Department use of an LRAD for crowd control in 2014 constituted 'excessive force' (United States Court of Appeals for the Second Circuit, *Edrei v Bratton*, Docket no. 17-2065, 13 June 2018). Similarly, under the Irish 1997 Non-Fatal Offences Against the Person Act, the definition of 'force' in relation to the offence of assault includes the application of 'noise' (Art 2(2)).

50 NATO, *The Human Effects of Non-Lethal Technologies*, p. G-4.

51 Art 35(2), 1977 Additional Protocol I (API) to the Geneva Conventions; ICRC Customary IHL Study, Rule 70.

52 Schrantz, 'The Long Range Acoustic Device', 58, citing a US Army legal review memorandum of 2007, at which time several hundred LRAD had already been deployed.

53 J. P. Winthrop, *Preliminary Legal Review of Proposed Acoustic Energy Non-Lethal Weapon Systems*, Department of the Navy, Office of the Judge Advocate General, 29 April 1998, pp. 8–9.

54 1995 Protocol on Blinding Laser Weapons (Protocol IV to the Convention on Certain Conventional Weapons); ICRC Customary IHL Study, Rule 86.

55 S. Casey-Maslen, *Non-Kinetic-Energy Weapons Termed 'Non-Lethal': A Preliminary Assessment Under International Humanitarian Law and International Human Rights Law*, Geneva Academy of International Humanitarian Law and Human Rights, October 2010, https://www.geneva-academy.ch/joomlatools-files/docman-files/Non-Kinetic-Energy%20Weapons.pdf; Altmann, 'Acoustic Weapons', 206.

56 Goodman, *Sonic Warfare*, p. 9. Parker reminds us that '[s]ound is experienced by the entire body' and 'is profoundly haptic' (Parker, 'Towards an Acoustic Jurisprudence', 203).

57 Goodman recognizes 'a tension between two critical tendencies tagged the politics of noise and the politics of silence' that constitute 'the typical limits to a politicized discussion of the sonic' (Goodman, *Sonic Warfare*, pp. 17–20). Parker notes that '[t]he LRAD's sheer volume means that, irrespective of what is being said, it will likely register affectively as a threat' (Parker, 'Towards an Acoustic Jurisprudence', 216).

58 Parker, 'Towards an Acoustic Jurisprudence', 206.

59 Art 51(4), API; ICRC Customary IHL Study, Rules 11 and 12.

60 A. Dymond-Bass and N. Corney, 'The Use of "Less-Lethal" Weapons in Law Enforcement', S. Casey-Maslen (ed.), *Weapons and International Human Rights Law*, Cambridge University Press, 2014, p. 42.

61 Altmann, *Millimetre Waves, Lasers, Acoustics for Non-Lethal Weapons?*, p. 49. See also W. M. Arkin, 'Acoustic Anti-Personnel Weapons: An Inhumane Future?', 13(4) *Medicine, Conflict and Survival* (2007) 320.

62 A Canadian review of the LRAD100X and the LRAD300X notes that 'within a city setting the sound levels of the LRAD could be 3 to 6 dB higher than in an open air environment' (Ministry of Community Safety and Correctional Services, *Review of Police Use of Long-Range Acoustic Devices*, p. 12, www.acoustical-consultants.com/wp-content/uploads/2012/03/LRAD-Report.pdf).

63 Art 3, 1990 UN Basic Principles on the Use of Force and Firearms by Law Enforcement Officials (BPUFF). Amnesty International has proposed guidelines for the implementation of the BPUFF with specific recommendations regarding non-lethal weapons testing and deployment and their use in crowd control (Amnesty International, *Use of Force: Guidelines for Implementation of the UN Basic Principles on the Use of Force and Firearms by Law Enforcement Officials*, 2015, Chapters 6 and 7, https://www.amnestyusa.org/reports/use-of-force-guidelines-for-implementation-of-the-un-basic-principles-on-the-use-of-force-and-firearms-by-law-enforcement-officials/.)

64 In particular, flash-bang devices have attracted severe criticism and legal challenges due to their capacity to cause severe injury and death. See, e.g., Angwin and Nehring, 'Hotter Than Lava'. On the right to health and non-lethal weapons generally, see E. Hoffberger, 'Non-Lethal Weapons: The Principle of Proportionality in Armed Conflict and the Right to Health in Law Enforcement', 38(2) *Zb. Prav. fak. Sveuč. Rij.* (2017) 844–847.

65 See, e.g., United States District Court for the Western District of Pennsylvania, *Karen L. Piper v. City of Pittsburgh et al*, Complaint, 21 September 2011. The case involved an LRAD and was settled. See also *Edrei v Bratton*, ruling that the New York City Police Department's use of an LRAD for crowd control in 2014 constituted 'excessive force'.

66 A German study warns that babies and young children are at particular risk of being exposed to the device for dangerously long periods because the adults accompanying them may not hear the sound and, thus, may not be able to protect them (German Federal Institute for Occupational Safety and Health, *Einsatz von Ultraschall-Störgeräusch-Sendern nicht ganz unbedenklich*, 14 December 2007, https://www.gesundheit-adhoc.de/einsatz-von-ultraschall-stoergeraeusch-sendern-nicht-ganz-un.html).

67 The French Tribunal de Grande Instance de Saint-Brieuc characterized it as an illegal sonic weapon (une 'arme sonore illicite'). See 'Le boîtier "antijeunes" interdit par la justice', *Le Monde*, 30 April 2008, https://www.lemonde.fr/societe/article/2008/04/30/le-boitier-antijeunes-interdit-par-la-justice_1040040_3224.html. For more detail, see Volcler, 'Le son comme arme'.

68 Volcler relates a 'Kafkaesque exchange' between people complaining about discomfort caused by a Mosquito illegally installed by a bank in Ixelles, Belgium, and police officers who can't hear anything and don't believe them (Volcler, 'Le son comme arme').

69 On 'subjection to noise' as a form of inhuman or degrading treatment, see, e.g., European Court of Human Rights, *Ireland v The United Kingdom*, App no. 5310/71, Judgment, 18 January 1978. (On 20 March 2018, the Court dismissed (pending request for referral to the Grand Chamber) an Irish request for revision of the judgment to the effect that the use of 'the five techniques of interrogation' amounted to torture, not merely inhuman and degrading treatment.) For a discussion of sound as torture, see Cusick, 'Music as Torture / Music as Weapon'.

70 See, e.g., G. Kerry and J. J. Bugge, *The NATO CCMS Working Group on Noise from Weapons – An Overview*, inter.noise 2000, 29th International Congress and Exhibition on Noise Control Engineering, 27–30 August 2000, Nice, France, www.conforg.fr/internoise2000/cdrom/data/articles/000842.pdf.

71 Altmann, 'Acoustic Weapons', 189.

72 NATO, *Reconsideration of the Effects of Impulse Noise*, RTO Technical Report TR-017, NATO doc AC/323(HFM-022)TP/17, April 2003, citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.214.6990&rep=rep1&type=pdf; Nakashima and Farinaccio, 'Review of Weapon Noise Measurement and Damage Risk Criteria', 404.

73 World Health Organization, 'Work-Related Noise', *The World Health Report* 2013, Chapter 4, http://www.who.int/whr/2002/chapter4/en/index8.html.

74 World Health Organization, '1.1 Billion People at Risk of Hearing Loss', Press Release, http://www.who.int/mediacentre/news/releases/2015/ear-care/en/.

75 See Parker, 'Towards an Acoustic Jurisprudence', 213–214.

76 The distance limits represent 'distances at which a sound level of 100 dBA [A-weighted decibels] would not be expected to be exceeded under the worst case conditions (full volume control setting, reflective ground surface, receptor located on the axis of the device at a location near a building) in the urban scenarios. Fifteen minutes of unprotected continuous exposure to 100 dBA corresponds to an equivalent sound exposure level over 8 hours [...] of 85 dBA.' (Ministry of Community Safety and Correctional Services, *Review of Police Use of Long-Range Acoustic Devices*, pp. 16–17).

77 Altmann, *Millimetre Waves, Lasers, Acoustics for Non-Lethal Weapons?*, p. 52. According to Altmann, to prevent permanent hearing damage from an LRAD, 'the warning tone must not be used closer than 5 m. The exposure duration has to be kept at a few seconds out to 50 m. Time limitations are needed to more than 100 m distance.' (p. 50)

78 Amnesty International and Omega Research Foundation, *The Human Rights Impact of Less Lethal Weapons and Other Law Enforcement Equipment*, 2015, p. 25, https://omegaresearchfoundation.org/publications/human-rights-impact-law-enforcement-equipment-april-2015.

79 N. Corney, *Less Lethal Systems and the Appropriate use of Force, Omega Research Foundation,* 2011, https://omegaresearchfoundation.org/sites/default/files/uploads/Publications/Less%20Lethal%20Systems%2C%20Corney%2C%202011.pdf; Amnesty International, *Use of Force*.