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Classification of Less Lethal Device Technologies

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PWGSC Contract Number: W7701-0691933/001/QLC (A.T. 46 PO 04134NG)
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Defence R&D Canada – Valcartier

Contract Report
DRDC Valcartier CR 2012-127
March 2012

Canada

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Abstract

Biokinetics was tasked by DRDC Valcartier as part of the CEWSI (Conductive Energy Weapon Strategic Initiative) to define a classification schema based on available information that can be used as part of an approval process to ensure that technologies to be approved are assessed using proper regulations and test protocols. This was achieved by conducting a review of source material that came from previous DRDC contracts, NATO and TTCP panel reports, as well as the internet. Results indicate that despite much research and discussion about device effectiveness, evaluation methodologies, and studies of human effects; there are not any product standards for less-lethal devices.

If occupational exposure standards exist for the particular agent being used, as they do for many types of noise, radiation and chemicals, then these standards should be followed when possible. However, such standards are highly conservative with large safety factors and therefore might not induce the desired response. In general, injury thresholds seem to be known for many of the major body regions and their related organs and systems. Combining this knowledge with device effectiveness and risk assessment methodology to create product performance and safety standards for less-lethal devices seems stalled in the research stage.

Résumé

Biokinetics a été chargé par RDDC Valcartier dans le cadre du CEWSI (conducteur Initiative arme stratégique de l'énergie) pour définir un schéma de classification de base sur les informations disponibles qui peuvent être utilisés dans le cadre d'un processus d'approbation afin de s'assurer que les technologies soient approuvés sont évalués à l'aide des règlements appropriés et protocoles d'essai. Ceci a été réalisé en procédant à une révision du matériel source qui venait de précédents contrats de RDDC, l'OTAN et les rapports des groupes TTCP, ainsi que l'internet. Les résultats indiquent que, malgré beaucoup de recherches et de discussions sur l'efficacité de dispositif, les méthodes d'évaluation, et études sur les effets de l'homme; il n'ya pas de normes de produits pour moins létales appareils.

Si les normes d'exposition professionnelle existent pour l'agent particulier qui est utilisé, comme ils le font pour de nombreux types de bruit, les rayonnements et les produits chimiques, alors ces normes doivent être suivies lorsque cela est possible. Toutefois, ces normes sont très conservatrices avec des facteurs de sécurité importants et donc peut-être pas induire la réponse souhaitée. En général, les seuils de blessures semblent être connus pour la plupart des régions du corps les grands et de leurs organes et des systèmes connexes. La combinaison de ces connaissances avec la méthodologie de l'efficacité périphérique et la création de la performance du produit et les normes de sécurité pour les moins meurtrières dispositifs semble au point mort dans le stade de la recherche.

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Executive summary

Classification of Less Lethal Device Technologies:

Doug Baines; DRDC Valcartier CR 2012-127; Defence R&D Canada – Valcartier; March 2012.

Introduction or background: Biokinetics was tasked by DRDC Valcartier as part of the CEWSI (Conductive Energy Weapon Strategic Initiative) to define a classification schema based on available information that can be used as part of an approval process to ensure that technologies to be approved are assessed using proper regulations and test protocols. From the list of technologies identified in the NATO Non-Lethal Weapon Technology Taxonomy the following list of in-service technologies and devices has been identified:

- Kinetic less-lethal devices (e.g. impact munitions of various calibers and launch platforms)
- Acoustic devices (e.g. hailing device, and underwater hailing devices)
- Laser devices (e.g. green laser interdiction system, and dazzlers)
- Chemical devices (e.g. pepper spray)
- Electrical devices (e.g. Taser)
- Multi-sensory devices (e.g. flash bangs)

These technologies and devices where identified based on their counter-personnel capabilities and their status within the U.S. Department of Defense Joint Non-Lethal Weapons Program as current non-lethal weapons. Current non-lethal weapons are fielded and in use. Human effects assessments have been conducted to identify the technology's anticipated physiological responses and risk of significant injury to the subject, bystander, and operator. However, access to this data is limited to pepper spray and Taser devices.

Source material came from previous DRDC contracts, NATO and TTCP panel reports, as well as various internet sources such as; the U.S. Defense Technology Information Center (DTIC), and the U.S. Department of Defense Joint Non-Lethal Weapons Program (JNLWP).

Results: Some occupational exposure standards exist for particular agents being used; as for many types of noise, radiation and chemicals, and these standards should be followed when possible. However, such standards are highly conservative with large safety factors and therefore might not induce the desired response. Other agents and technologies are without guidance on safe limits.

Significance: The possible human effects of less-lethal devices range from medical, to group psychology and from the acute to the long-term. The human effects issues concerning less-lethal devices are not unlike those related to therapeutic drugs; there are desired effects, there are

undesired effects, and there is a useful region in between the two extremes. These effects can be characterized by plotting the probability of a response versus some measure of the less-lethal device strength, the so called dose-response curve.

In general, injury thresholds seem to be known for many of the major body regions and their related organs and systems. However, despite the human effects data collected so far, defining the threshold between no-response, the desired response, and injury is not as well defined. Combining this knowledge with device effectiveness and risk assessment methodology to create product performance and safety standards for less-lethal devices seems to be stalled in the research stage. In the absence of industry regulations and standards strong product claims can be made without evidence or references.

Future plans: Identifying all of the intended and unintended effects both acute and chronic for both the user and the subject is required not only for the technology class but in some cases for the particular devices within that class.

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1 Introduction

Less lethal devices are designed to fill the gap between the shout and shoot responses, however they bring with them some new challenges to the law enforcement acquisition community and program managers who are tasked with characterizing the effects and effectiveness of less-lethal devices on their subjects. Currently there is no policy or guidance and they must rely on their own discretion. The purpose of this report is to identify the less-lethal technologies and devices currently available in the public domain and to identify criteria and protocols to test against. A less-lethal device taxonomy that will facilitate an approval process for law enforcement and corrections is desired, such that technologies to be approved are assessed using proper regulations and test protocols to determine whether or not the device meets the law enforcement definition of less-lethal (to be determined) and presents low risks of short and long term injuries to the civilian population. Excluded from this report are considerations given to legal assessments, and operational policies and procedures.

The current NATO Non-lethal Weapon (NLW) Technology Taxonomy categorizes possible NLW technology types and was developed by the NATO SAS-035 study which is based on the US Joint NLW directorate Taxonomy (Table 1). Specific NLW systems that use these and other technologies must comply with treaty and legal obligations.

Table 1 NATO Non-Lethal Taxonomy

Electro-Magnetic	Chemical	Acoustic	Mechanical Kinetic	Ancillary
Electrical Pulsed Current Direct Current **Radio Frequency** EMP Wide Band Ultra Wide Band **Microwave** High Power Microwave **Millimetre Wave** **Infrared** Lasers COIL* CO_2** HF/DF*** Solid State **Visible** Lasers Lights **Ultraviolet** Lasers **X-Rays**	**Obscurants** Rapid Hardening Agents Smokes **Reactants** Super-Corrosives Combustion Altered Viscosity Combustion Altered Fuel-Air Lubricant Contaminants Depolymerizers Embrittlers Emulsifiers **Malodorants** **Riot Control** **Anti-Traction** Lubricants Surfactants **Foams** **Thermobaric** **Nano-Particles**	**Audible** (20 Hz-20 KHz) **Audible/Optical** Flash Bangs **Ultrasound** (>20 KHz)	**Barriers** **Entanglements** Nets **Cloggers** **Blunt Impact** Projectiles Velocity Adjusting Water Stream **Vortex Ring Gun**	**Marker** Dyes Fluorescent Paints Taggers **Non-Lethal Casings** Frangible Combustible **Encapsulants** Micro-encapsulation

* COIL - Chemical Oxygen Iodine Laser
** CO_2 - Carbon Dioxide
*** HF/DF - Hydrogen Fluoride/Deuterium Fluoride

The following list of less-lethal devices was identified for review in this report based on the device's counter-personnel capabilities and its status within the U.S. Department of Defense Joint Non-Lethal Weapons Program as current non-lethal weapons. Current non-lethal weapons are fielded and in use. Human effects assessments have been conducted to identify the technology's anticipated physiological responses and risk of significant injury to the subject, bystander, and operator. However, access to these assessments is limited to pepper spray and Taser devices.

- Kinetic less-lethal devices (e.g. impact munitions of various calibers and launch platforms)
- Acoustic devices (e.g. hailing device, and underwater hailing devices)
- Laser devices (e.g. green laser interdiction system, and dazzlers)
- Chemical devices (e.g. pepper spray)

- Electrical devices (e.g. Taser)
- Multi-sensory devices (e.g. Flash Bangs)

Counter-materiel less-lethal weapons, and those still in development are outside the scope of this report.

By reviewing the device characteristics, as well as the intended and unintended effects of these devices, this report attempts to summarize the effects of concern and to identify test procedures that can be used to evaluate the performance and safety of these devices.

Some occupational exposure standards exist for a particular agent being used, as for many types of noise, radiation and chemicals, and these standards should be followed when possible. However, such standards are highly conservative with large safety factors and therefore might not induce the desired response. Other agents and technologies are without guidance on safe limits.

The possible human effects of less-lethal devices range from medical, to group psychology and from the acute to the long-term. The human issues concerning less-lethal devices are not unlike those related to therapeutic drugs; there are desired effects and there are undesired effects and there is a useful region in between the two extremes. These effects can be characterized by plotting the probability of a response versus some measure of the less-lethal device strength, the so called dose-response curve.

In general, injury thresholds seem to be known for many of the major body regions and their related organs and systems. However, despite the human effects data collected so far, defining the threshold between no-response, the desired response, and injury is not as well defined. Combining this knowledge with device effectiveness and risk assessment methodology to create product performance and safety standards for less-lethal devices seems to be stalled in the research stage. In the absence of industry regulations and standards strong product claims can be made without evidence or references.

A classification scheme based on the NATO taxonomy with consideration given to the various effects of exposure to less-lethal devices is proposed. This will allow for the inclusion of new technologies as they become available. Since many of the major body regions and their related organs and systems have known injury thresholds this will help to identify proper test methods. This is in keeping with existing approaches to trauma prediction that include survivability-lethality-vulnerability (SVL) models to assess the interaction of conventional threats such as projectiles and fragments. The critical elements include models of the threat and delivery to the subject, their interaction with the anatomy and physiology, and injury outcome assessments based upon available injury criteria. Less-lethal devices include some unique threats not currently found in these models, but building upon and using these existing evaluation tools seems a natural evolution.

2 Kinetic Devices

2.1 Blunt Force Effects

1.1.1 Definition

Blunt trauma comprises any injury that is sustained from blunt force caused by impact, injury, or physical attack; the latter usually being referred to as blunt force trauma. Motor vehicle accidents are the most common cause of blunt trauma but other mishaps from falls, blows or crush injuries from blunt objects are also possible causes. The term blunt trauma may encompass concussions, abrasions, bruising, ruptures, lacerations, and bone fractures. Blunt force trauma differs from penetrating trauma, in which a projectile enters the body, although both have the ability to cause pain and internal injury [1].

1.1.2 Device Description

Projectile, Blunt Impact and other Kinetic Devices: Devices intended to impart kinetic energy and cause temporary physical pain, resulting in deterrence, distraction, incapacitation, and a reduced motivation. Also, hollow projectiles can be filled with chemicals, dyes, or other substances that are released upon impact. Depending on energy, range, ricochet, bounce, location of impact, and the sensitivity of the individual, such devices can result in undesired injuries such as severe bruising, broken bones, contusion, concussion, eye damage, and are potentially lethal [2].

1.1.3 Effects of Concern

Many surveys, Post Mortem Human Subject (PMHS) studies, animal studies and incident reports have been published to assess the type and severity of injuries that occurred as consequence of Kinetic Energy Non-Lethal Weapons (KENLW) projectile impact. In summary, the following injuries can be expected[3]:

- At the site of impact: abrasion, contusion, laceration and penetration of the projectile, or part of it
- Away from the site of impact: bone fracture, crushing of organs, hemorrhages.

Depending on the projectile impact location and the energy at which it hits the target, a large range of consequence can occur, including death. The following non exhaustive list of injuries from either penetration or blunt impact of KENLW has been reported[3]:

- Head and face impacts: skull and facial bone fracture can occur with possible brain hematomas
- Eye impacts: globe rupture and corneal abrasion and laceration
- Thoracic impacts: rib fracture, heart concussion and contusion and lung contusion
- Abdominal impacts: rupture and laceration of abdominal internal organs

- Upper and lower extremities impacts: open or closed fractures of long bones

In the references mentioned above, head impact is pointed out as the most frequent cause of death and serious injuries followed by the thoracic region which suggests that the impact location is a primary factor in the outcome of KENLW use. Manufacturers' literature and impact munitions training programs typically advise officers to direct their aim towards extremities and larger muscle areas and away from others (e.g., head, neck, spine, liver and kidney areas) based on the assumption that more serious injuries are more likely to occur when subjects are struck in critical areas. It is therefore essential to train soldiers and police officers effectively and to provide them with accurate KENLW devices to reach the desired effects on the target[3].

1.1.4 Safe Exposure Limits

There are no formal exposure limits for kinetic energy less-lethal weapons (KELLW), although there is research to suggest that blunt trauma injury thresholds are known for the various anatomical regions.

1.1.5 Standards

Although no formal NIJ KELLW standard currently exists for the evaluation of less-lethal munitions, Wayne State University (WSU) has developed an internal test methodology to assess the injury potential of these munitions. Three factors (for kinetic energy munitions) are considered: accuracy, thoracic blunt trauma, and penetrating trauma [4]. NATO LCG-9 (Land Capability Group-9) on NLW have stood up a working group of experts in March 2010 with the goal of standardizing test methods for the assessment on injuries caused by blunt impact NLW. The group of expert has divided the work as follows: head/face impacts, thoracic impacts, abdominal impacts, penetration assessment and accuracy. The different test methods available within NATO countries are analysed and injury criteria's are proposed. At the time of writing this report the first version of the standard concerning penetration assessment is planned for September 2012.

Accuracy and Precision Assessments

The accuracy of a projectile is assessed at various ranges [up to 100 m] based on operational firing distances. A circle of precision is used to determine how tightly a ten shot grouping can be made at various distances. KENLW projectile are relatively unstable. Therefore, in flight attitude of the projectile has to be determined using high-speed video analysis.

Penetration Assessments

The risk of penetrating trauma caused by KENLW is important and has been reported frequently. One factor to consider is the amount of energy generated by the munition. In addition, it is important to determine the energy per unit area or E/a (J/cm^2) value to assess penetration capability. This value takes into account the mass, velocity, and the cross-sectional area of the projectile. Simply reporting energy is insufficient for comparison of different samples and projectiles. Penetration assessment is done by the evaluation of penetration in a surrogate

composed of 20% ballistic gelatin, foam, and natural chamois. This testing is typically done at a range that represents the worst case or minimum suggested range. Accuracy of the projectile is critical for this testing due to the surface area restrictions of the penetration surrogate.

Blunt Trauma Assessments

The risk of blunt trauma to the thorax has been assessed by using an empirically based injury criterion called the viscous criterion (VC). This criterion has used extensively for motor vehicle occupants to predict the severity of injury. The VC is calculated based on the amount of thoracic compression and the velocity at which this compression occurs. The amount of thoracic compression was defined as the displacement of the chest in relationship to the spine normalized by the initial thickness of the thorax. VC has been validated as a useful tool in determining injury severity related to blunt ballistic impacts to the thorax. Blunt trauma assessment of less-lethal munitions is conducted at Wayne State University with the 3-RBID ballistic impact surrogate. This testing is also typically done at a range that represents the worst case, or minimum suggested range. Accuracy of the projectile is again critical for this testing due to the surface area restrictions of the 3-RBID. Biokinetics and Associates have developed a Blunt Trauma Torso Rig (BTTR) with a larger surface area that may be a useful tool once a test methodology has been adopted.

Head and face surrogate devices exists to evaluate the risk of skull fracture (Ballistic Load Sensing Headform – BLSH – from Biokinetics) and the risk of facial bone fracture and eye injuries (FOCUS head, USAARL). A test method to assess skull fracture was determines for behind armour blunt trauma (BABT) behind ballistic helmets under CSA Z613. The test method can be adapted to KENLW, but as of now, no test methodology has been adopted.

1.1.6 Associated Technologies and Device Characteristics

12-gauge munitions

The 12-Gauge Munitions are designed to deny individuals access into/out of an, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, checkpoints, patrols/convoys, and crowd control.

These munitions are shotgun rounds that are designed to deliver blunt trauma effects to individuals. Multiple Services currently employ these rounds. Different types of 12-gauge munitions are available such as stingball rounds, fin stabilized rounds, and sock rounds [5], to list a few.

40 mm Munitions

The 40 mm Munitions are designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, access control points, patrols, and crowd control.

Amongst other, the M203 grenade launcher can deliver blunt trauma effects to individuals using these rounds. Multiple Services currently employ these rounds. Different types of 40 mm munitions are available such as sponge rounds, foam rubber baton rounds, and crowd dispersal cartridges [5].

66 mm Light Vehicle Obscurant Smoke Systems and Vehicle Launched Less-Lethal Grenades

The 66 mm Light Vehicle Obscurant Smoke System and Vehicle Launched Less-Lethal Grenades are designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals.

This technology has the potential to support multiple missions including: force protection, crowd control, offensive and defensive operations.

The Light Vehicle Obscurant Smoke System and Vehicle Launched Less-Lethal Grenades is a remotely fired launcher that discharges a 4 grenade single salvo. The grenades are capable of delivering smoke, flash bang effects, Riot-Control Agent munitions and blunt trauma[5].

FN-303 Less-Lethal Launching System

The FN-303 Less Lethal Launching System is designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, detainee operations, crowd control, defensive and offensive operations.

The FN-303 is a compressed-air powered launcher designed to fire Less-Lethal projectiles. Projectiles include a training/blunt impact, marking (washable-pink, permanent-yellow), and Oleoresin Capsicum liquid[5].

Modular Crowd Control Munitions

The Modular Crowd Control Munition is designed to deny individuals access into/out of an area and suppress individuals. This technology has the potential to support multiple missions including: entry control points, defensive actions, and crowd control.

The Modular Crowd Control Munition is the same dimension as a Claymore Mine and is capable of blunt trauma impact. The explosive munition sends 600 rubber balls out at high speeds to suppress subjects[5].

Stingball Grenade

The Stingball Grenade is designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, clear rooms, and crowd control.

The Stingball Grenade is hand thrown or can be fired out of a 12-gauge launch cup for further range. The cartridge consists of a fuse, a separating fuse body, a black powder separation charge, a pressed black powder delay, a bursting charge of flash powder, and rubber pellets. When it explodes the rubber pellets hit the subject with blunt force.

3 Acoustic Devices

3.1 Aural Effects

1.1.7 Definition

There are two basic types of Noise Induced Hearing Loss (NIHL); acoustic trauma from acute exposure, and gradually developing through chronic exposure. Acoustic trauma is injury to the hearing mechanisms in the inner ear (cochlear damage) due to very loud noise (excessive sound pressure). Gradually developing NIHL refers to permanent cochlear damage from repeated exposure to loud sounds over a period of time[6].

1.1.8 Device Description

Devices intended to utilize 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. A large variety of acoustic devices have been proposed for less-lethal applications. Most are of uncertain effectiveness and many could damage hearing[2]. We have focused here on audible acoustic devices currently available to law enforcement and corrections.

1.1.9 Effects of Concern

Noise induced permanent hearing loss.

1.1.10 Safe Exposure Limits

For the purpose of this discussion there are two main categories of individuals to consider; operators and subjects.

Operators may be exposed to noise produced by these devices on repeated occasions and their exposure should fall within well-established occupational exposure limits defined by the Canadian Centre for Occupational Health and Safety (CCOHS). Occupational exposure limits (OELs) for noise are typically given as the maximum duration of exposure permitted for various noise levels. They are often displayed in exposure-duration tables. The OELs depend on two key factors that are used to prepare exposure-duration tables: the criterion level and the exchange rate[7]. The criterion level, often abbreviated as Lc, is the steady noise level permitted for a full eight-hour work shift. This is 90 dB(A) in most jurisdictions, but in some jurisdictions it is 85 dB(A). The exception is in the Canadian federal noise regulations where the criterion level is 87 dB(A). As the sound level increases above the criterion level, Lc, the allowed exposure time must be decreased. The allowed maximum exposure time is calculated by using an exchange rate, also called a "dose-trading relation" or "trading ratio." The exchange rate is the amount by which the permitted sound level may increase if the exposure time is halved[7].

Occupational exposure limits for subjects of acoustic effects is inappropriate, given that subjects will likely only receive a single exposure and there are no recognized safety limits for these

subjects[8]. However, the Directorate of Force Health Protection Canadian Forces Health Services Group Headquarters has developed Occupational Health Recommendations Regarding the Safe Use of the LRAD-1000X in Maritime Operations which recommends exposure limits for single exposure to continuous high intensity sound based on existing human research.

1.1.11 Standards

Currently there are no industry standards for less-lethal acoustic devices.

MIL-STD-1474D standard establishes acoustical noise limits and prescribes testing requirements and measurement techniques for determining conformance to the noise limits specified therein. This standard was established for the military environment (including single exposure high level low duration noises like blast) and is the result of long term, still continuing research on the subject. Although not perfect, this standard can be used to assess the effects of exposure to acoustic devices. LRAD Corporation's product specification sheets indicate that their products meet MIL-STD-1474D

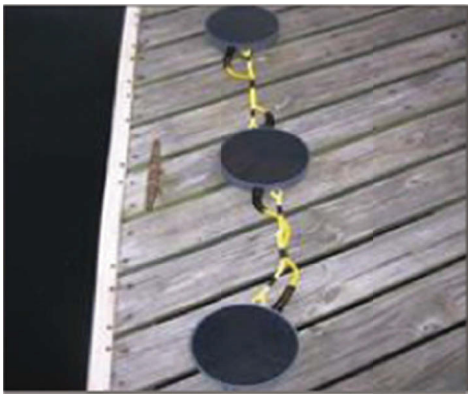
1.1.12 Associated Technologies and Device Characteristics

Acoustic Hailing Devices

Acoustic Hailing Devices (like the LRAD for example) are designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, checkpoints, patrols and convoys, and crowd control.

Acoustic Hailing Devices provide scalable, directional warning tones or intelligible voice commands beyond 500 meters. They can be vehicle, vessel and ground mounted [5]. At high power, the sound pressure level (SPL) can be damaging for targets at short range.

Enhanced Underwater Loudhailer



The Enhanced Underwater Loudhailer is designed to deny access into/out of an area and suppress underwater swimmers and divers. This technology has the potential to support multiple missions including: force protection, and port security.

The Enhanced Underwater Loudhailer is a man-portable, easy-to-operate unit comprised of a control unit and a 75-foot transducer cable. The unit transmits intelligible commands capable of auditory impairment up to 2 hours with a battery source, to a distance of 457 meters and depth of 40 meters [5].

4 Optical Devices

4.1 Ocular Effects

1.1.13 Definition

Optical radiation refers to those parts of the electromagnetic spectrum broadly divided into three spectral bands; ultraviolet (UV), visible (VIS), and and infrared (IR). UV and IR are further subdivided into various spectral bands. Laser radiation predominantly causes injury via thermal effects. Even moderately powered lasers can cause injury to the eye. High power lasers can also burn the skin. Some lasers are so powerful that even the diffuse reflection from a surface can be hazardous to the eye. Non-Coherent optical radiation (sources other than laser) can also damage the eye.

1.1.14 Device Description

Electromagnetic – Visible and Invisible Light and Lasers: Most less-lethal technology concepts utilizing light are intended to temporarily disrupt vision. Vision disruption can occur by glare from direct exposure to the light source, glare from reflections from the light source or from flashblindness occurring after exposure. These effects are stronger in low background illumination environment like at night or in low light conditions principally because of the dilatation of the pupils under those circumstances.

1.1.15 Effects of Concern

The eye and skin are the organs most susceptible to damage by laser radiation[9]. The primary effect of concern for the eye is caused by irradiation of the retina by high level of light energy. For skin the effect is related to burns caused by the thermal load generated by the light source. The type of effect, injury thresholds, and damage mechanisms vary significantly with wavelength, intensity, duration, and the frequency of its impact [9]. Secondary effects due to visual impairment are also of concern[2].

1.1.16 Safe Exposure Limits

Lasers

Laser safe exposure limits exists to minimize the risk of laser accidents, especially those involving eye injuries.

Moderate and high-power lasers are potentially hazardous because they can burn the retina of the eye, or even the skin. To control the risk of injury, various specifications, for example ANSI Z136 in the US and IEC 60825 internationally, define "classes" of laser depending on their power and wavelength. These regulations also prescribe required safety measures, such as labelling lasers with specific warnings, and wearing laser safety goggles when operating lasers.

The Maximum Permissible Exposure (MPE) and the Nominal Ocular Hazard Distance (NOHD) are the most important parameters of laser safety. The MPE is the highest power or energy density (in irradiance - W/cm^2 - or radiance exposure - J/cm^2 -) of a light source that is considered safe i.e. that has a negligible probability for creating damage. It is usually about 10% of the dose that has a 50% chance of creating damage[8] under worst-case conditions. The MPE is measured at the cornea of the human eye or at the skin, for a given wavelength and exposure time.

The evaluation of these parameters requires a detailed knowledge of the standards and of the various techniques which are necessary to measure them. The experimental values of irradiance must be compared with the MPE parameters obtained by safety standards. When the values of irradiance exceed the MPE parameters then the NOHD values must to be calculated.

A calculation of the MPE for ocular exposure takes into account the various ways light can act upon the eye. For example, deep-ultraviolet light causes accumulating damage, even at very low powers. Infrared light with a wavelength longer than about 1400 nm is absorbed by the transparent parts of the eye before it reaches the retina, which means that the MPE for these wavelengths is higher than for visible light. In addition to the wavelength and exposure time, the MPE takes into account the spatial distribution of the light (from a laser or otherwise). Collimated laser beams of visible and near-infrared light are especially dangerous at relatively low powers because the lens focuses the light onto a tiny spot on the retina. Light sources with a smaller degree of spatial coherence than a well-collimated laser beam, such as high-power LEDs, lead to a distribution of the light over a larger area on the retina. For such sources, the MPE is higher than for collimated laser beams. In the MPE calculation, the worst-case scenario is assumed, in which the eye lens focuses the light into the smallest possible spot size on the retina for the particular wavelength and the pupil is fully open. Although the MPE is specified as power or energy per unit surface, it is based on the power or energy that can pass through a fully open pupil (0.39 cm2) for visible and near-infrared wavelengths. This is relevant for laser beams that have a cross-section smaller than 0.39 cm2. The IEC-60825-1 and ANSI Z136.1[10] standards include methods of calculating MPEs[11].

The Joint Non-Lethal Weapons Program in the United States has identified an eye safe irradiance of 100 $\mu W/cm^2$ as causing enough glare to temporarily and effectively obscure a persons field of vision.

Non-coherent Optical Radiation

The optical properties of lasers are special and differ significantly from those of conventional, broad-band optical sources, and so the exposure limits for broad-band optical sources necessarily differ from those applicable to lasers. In addition, laser guidelines incorporate assumptions of exposure that may not apply to conventional optical sources. Most lasers emit radiation over one or more extremely narrow wavelength bands, and no detailed knowledge of the spectral output is required for purposes of hazard evaluation. By contrast, evaluation of the potential hazards of broadband conventional light sources requires spectraradiometric data to apply several different photobiological action spectra, as well as knowledge of the exposure geometry. The action spectra may apply to different ocular structures and the biological effects are not additive. Adverse health effects of exposure to intense light sources are theoretically possible across the entire optical spectrum, but the risk of retinal injury due to radiation in the visible and near-infrared is of particular concern. Exposure lintits vary enormously across the optical spectrum

because of variations in biological effects and the different structures of the eye that are potentially at risk **[12]**.

Guidelines on exposure limits for non-coherent visible and infrared radiation have been put forward by the International Commission on Non-Ionizing Radiation Protection [12], and are currently being updated[13]

1.1.17 Standards

There are currently no industry standards for less-lethal optical devices in particular. However, industry standards do exist for laser safety, one of which is the American National Standard for Safe Use of Lasers (ANSI Z136.1)[10]. This standard provides recommendations for the safe use of lasers and laser systems that operate at wavelengths between 180 nm and 1 mm.

Manufacturers measured laser safety in terms of MPE and NOHD as defined by the ANSI Z136.1 standard for laser safety, and provide a recommended safe stand-off distance.

No product standards for exposure to optical radiation have been proposed. But because there are differences between broad-band incoherent optical sources and monochromatic laser sources, and between the worst-case conditions for the two, and because a number of simplifying assumptions were used to derive laser exposure limits, it is necessary to recommend different exposure limits that are more realistic for incoherent sources[12].

The following standards and guidelines might offer a way forward and offer insight into the proper safety assessments of less-lethal devices utilizing optical radiation:

1. ANSI Z136.1[10]

2. International Commission on Non-ionizing Radiation Protection (ICNRP) [9] [12] [13]

3. Directive 2006/25/EC of the European Parliament and of the Council of 5 April 2006 on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) [14].

1.1.18 Associated Technologies and Device Characteristics

Green Laser Interdiction System

The Green Laser Interdiction System (GLIS) is designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, checkpoints, maritime ports/security zones, entry control points, and deny, move, and suppress individuals on foot/operating vessel.

The GLIS is a rifle-mounted/hand-held laser that allows interdiction of potential hostile actions through less-lethal effects and is interchangeable between host weapon platforms. It is an effective less-lethal means to inform (warn) civilians that are approaching military operations with visible effects from 0-300 m. This ocular impairment device is handheld, but can be mounted on a rifle or crew served weapon[5]. These devices are commonly referred to as dazzlers and are available from numerous manufactures with various models offering continuous wave or pulsed mode.

The colour green was chosen due to the fact that the human eye is four times more sensitive to green light than to red light during the day, and 363 times more sensitive to green at night.

Other Optical devices

Laser devices where identified based on their counter-personnel capabilities and their status within the U.S. Department of Defense Joint Non-Lethal Weapons Program as current non-lethal weapons. Current non-lethal weapons are fielded and in use. Human effects assessments have been conducted to identify the technology's anticipated physiological responses and risk of significant injury to the subject, bystander, and operator. Other optical devices operating in various wavelengths, although available, are beyond the scope of this report due to the lack of data.

5 Chemical Devices

5.1 Toxic Effects

1.1.19 Definition

Toxicity is the ability of a substance to produce an unwanted effect when the chemical has reached a sufficient concentration at a certain site in the body. The more toxic a material is, the smaller the amount required for harmful effects to occur . The toxicity of a chemical is generally measured by experiments on animals. It is measured in terms of the amounts of material necessary to cause death in 50% of the test animals. These values are called LD50 (lethal dose) or LC50 (lethal concentration), and are usually given in weight of material per kg of body weight or airborne concentration of material per set time period respectively[9].

1.1.20 Device Description

Chemicals for Anti-Personnel Applications: Pharmaceuticals, irritants, and lubricants, have been proposed for a variety of anti-personnel applications. Possibilities for undesired human effects are significant and depend on the amount of exposure (dose) to the agent, its means of entry into the body (e.g., skin for liquids, respiratory for gasses), and access to sensitive organs (e.g., the eye). While some of these compounds are used by domestic police, their use by multinational forces and in warfare is limited by laws and treaties[2].

The predominant agents used in law enforcement and corrections are normally referred to as Riot Control Agents (RCAs) – despite the fact that they have much broader tactical application for law enforcement than crowd management and riot control. Internationally, RCAs are defined as:

Any chemical not listed in a Schedule [lists of chemicals prohibited under the Chemical Weapons Convention] which can produce rapidly humans sensory irritation or disabling physical effects which disappear within a short time following termination of exposure[15].

RCA's fall into one or more of the following five technology categories: Malodorant Agents, Irritant Agents, Smoke, Marking Agents, and Calmative Agents.

A physiological classification of materials identifies toxic materials based on their biologic action, as follows: irritants, asphyxiants, narcotics or anaesthetics, systemic poisons, carcinogens, mutagens, teratogens, and sensitizers[16].

1.1.21 Aerosol Subject Restraints (ASR's)

Delivery Modes

There are three primary delivery modes; stream, cone spray (large aerosol droplets), fogger (small aerosol droplets).

Effects of Concern

The intended effects of OC/PAVA sprays are irritation and incapacitation. Ocular irritation is the primary effect, followed by respiratory and skin irritation. The stream and cone sprays are expected to cause blepharospasm if the spray reaches the eyes. For these devices, pressure injury to the eyes may pose a significant risk of severe eye damage. Aspiration of inert liquid for the stream or cone spray device investigated was not a concern based on estimates of the volume of liquid entering the mouth, but data gaps prevent elimination of concern for this effect. The risk of flammability relates to the potential for ignition of solvents or propellants by a flame or a spark[17].

For the fogger device, induction of intended respiratory effects would be expected within a minute or less. Very sensitive asthmatics may develop bronchoconstriction at exposures less than those that cause the intended effect in healthy individuals. These sensitive asthmatics are likely to also have lower thresholds for the intended effect than healthy individuals, but quantitative information on these relative thresholds was not available. There is also very wide variability in the response among asthmatics. Healthy individuals may be at some risk for bronchoconstriction, but the dose that causes bronchoconstriction in healthy individuals is not well defined. There may be a risk of effects on the deep lung for the fogger, and this risk will increase with foggers that have low levels of solids, but the data are not sufficient to translate this potential into a probability of an effect[17].

The Biobehavioral Systems Branch (AFRL/RHDJ) conducted a Human Effectiveness and Risk Characterization (HERC) for oleoresin capsicum (OC) and pelargonic acid vanillylamide (PAVA or nonivamide) hand-held devices. The active ingredients in these devices are collectively termed capsaicinoids, and act by peripheral sensory irritation. OC and PAVA sprays are a diverse set of more than 300 commercially available products. Because the HERC team was not able to identify sufficient information on any one product to allow the development of a product-specific assessment of risk and effectiveness, the HERC instead evaluated three illustrative devices (a stream spray, cone spray, and fogger) that are believed to generally represent the range of devices commercially available[17].

The HERC presented a characterization of the likelihood of intended and unintended effects from the use of these devices. Overall, the results indicate that the use of the devices as intended would generally be effective in inducing the desired effect of peripheral sensory irritation without presenting a significant risk of unintended severe effects. Although likely to be uncommon, severe unintended effects might occur. In some cases, key data gaps and uncertainties preclude the evaluation of effectiveness and risk. These overall conclusions regarding effectiveness and risk are consistent with; the current experience with OC and PAVA devices in the field, limited empirical data (primarily on the related chemical, capsaicin, as well as some data on PAVA), as well as human effects or safety assessments developed by others[17].

Seven effects (two potentially intended and five unintended) were of sufficient concern and had adequate data to include in a quantitative dose-response assessment[17].

- Intended – eye irritation, and respiratory irritation

- Unintended – pressure injury to the eye, bronchospasm, pulmonary effects, aspiration, impact from canister and flammability. All unintended effects are potentially severe.

The spray is intended to cause a burning sensation in the eyes, nose and mouth. Contact with OC particles incapacitates subjects by causing an almost immediate burning of the skin, and a burning, tearing and swelling< of the eyes. This exposure to the OC can cause severe blepharospasm (twitching or spasmodic contraction) of the eyes and even involuntary closing of the eyes When the agent is inhaled, the respiratory tract is inflamed, resulting in a swelling of the mucous membranes lining the breathing passages, and temporarily restricting breathing to short, shallow breaths. Inhalation causes coughing and shortness of breath. This, in turn, causes a gagging reflex and gasping for breath. This has been reported to be a response to bronchoconstriction, a constriction of the airway. Repeated exposure can cause tachyphylaxis, a decreasing response following consecutive administration. Furthermore, if a significant amount of the aerosolized product reaches the pulmonary or alveolar region, where air exchange takes place, it may greatly interfere with essential respiration. This is a primary concern for aerosols generating a mist or a fog where the aerodynamic particle size is much smaller, thus potentially allowing an excess amount of active ingredient to travel to the alveolar region[18].

The HERC report concluded that their analyses suggest that, despite significant data gaps in exposure and toxicity, devices that spray liquids containing OC and PAVA are generally effective devices, achieving a significant degree of compliance that appear to have a limited potential for moderate to severe unintended effects. This conclusion is consistent with several other recent evaluations of OC or PAVA. However, there are significant and important uncertainties in the effects assessment, particularly regarding dose-response for respiratory effects of small-droplet-size aerosols and the estimates of inhalation exposure and physical impact of droplets on the eye. The potential for occurrence of the various effects evaluated in this HERC can be summarized as follows:

- Eye effectiveness – expected for both the cone and stream, as long as the spray reaches the eyes; not effective for the fogger.

- Pressure injury to the eye – not a concern for the fogger; streams or cone sprays that produce droplets (greater than 26 m/s) may pose a significant risk of severe eye damage.

- Respiratory effectiveness – expected within 1 minute or less for the fogger.

- Bronchoconstriction in sensitive asthmatics - not expected for the stream or cone sprays; may occur within 1 minute or less for both fogger scenarios, but the fraction of the population where this effect will occur is not known, due to considerable variability among asthmatics.

- Bronchoconstriction in healthy individuals – not expected for the cone spray or stream; there may be some risk for bronchoconstriction in healthy individuals from foggers, but the dose that causes bronchoconstriction in healthy individuals is not well defined.

- Pulmonary effects – not expected for the cone spray or stream; there may be a risk of pulmonary effects for fogger and this risk will increase with foggers that have low levels

of solids, but the data are not sufficient to translate this potential into a probability of an effect.

- Aspiration of liquid – not a concern for the fogger; not a risk based on aspiration of inert liquid for the stream or cone spray device investigated in this study. However, the lack of data on the actual amount used and the frequency of use at a distance of less than a meter prevent the elimination of concern for this effect.

- The risk of flammability depends on the solvent mixture. The available data suggest that the 50% ethanol, 50% water mixture used in the hypothetical three devices assessed in this report have the potential for being ignited under certain circumstances.

1.1.22 Safe Exposure Limits

In order for a substance to affect health, it must contact the body or be absorbed into the body. When assessing the potential health effects from working with a particular substance it is necessary to understand the difference between "toxicity" and "hazard".

Toxicity is the ability of a substance to produce an unwanted effect when the chemical has reached a sufficient concentration at a certain site in the body. The more toxic a material is, the smaller the amount of it necessary to be absorbed before harmful effects are caused.

Hazard is the probability that this concentration in the body will occur. Toxicity is an inherent property of the material. A material may be very toxic, but not hazardous, if it is handled properly and is not absorbed into the body. On the other hand, a material may have a very low toxicity, but be very hazardous[16].

There are three primary routes of entry into the body; ingestion, skin or eye absorption, and inhalation. Once a toxic substance has contacted the body it may have either acute (immediate) or chronic (long-term) effects. Exposures are also classified as acute (single event) or chronic (some frequency over a period of time).

Manufacturers provide Material Safety Data Sheets (MSDS) with their products. The MSDS lists the hazardous ingredients in the product along with any exposure limits, counter measures and other safety information. In Canada the program known as the Workplace Hazardous Materials Information System (WHMIS) establishes the requirements for Material Safety Data Sheets (MSDSs) in workplaces and is administered federally by Health Canada under the Hazardous Products Act, Part II, and the Controlled Products Regulations. WHMIS and MSDS requirements are also enforced by provincial Ministries or Departments of Labors Chemical Abstract Service (CAS). CAS Registry Numbers are unique numerical identifiers assigned by the "Chemical Abstracts Service" to every chemical described in the open scientific literature (currently including those described from at least 1957 through the present). The Registry maintained by CAS is an authoritative collection of disclosed chemical substance information, including; hazards, risk codes, and safety descriptions.

Oleoresin Capsicum (OC)

Acute oral LD_{50} values in humans have been estimated at 0.5-5.0 g/kg. Acute dermal exposure can cause skin irritation, but no exposure limits have been found. Acute inhalation exposure to capsaicin temporarily causes bronchoconstriction, coughing, nausea, and incoordination in the upper body in humans[19], but no industry exposure limits have been defined.

Permissible Exposure Limits (PEL) as defined by the United States Department of Labour's Occupational Safety and Health Administration (OSHA) have not been established for worker safety. First Defense conducted a study where the one minute acute inhalation LC_{50} values in rats was estimated to be greater than 5.76 mg/L using a First Defense OC product (no mortalities occurred). It was determined that the possibility of generating an aerosol concentration of 5.76 mg/L in an outdoor application is almost unachievable, and the ability to sustain that concentration for a one-minute continuous exposure would be difficult to produce[20].

No effective dose for this less-lethal device has been defined. Although, anecdotal information suggests that it is generally accepted by law enforcement and corrections training professionals that the use of Aerosol Subject Restraints (ASR's) with a Scoville Value exceeding 200,000 would be unsuitable for normal duty use[21].

Chloroacetophenone (CN)

Yasser Al-Zayyat, AFP / Getty Images

Chloroacetophenone is the only riot control/tear agent listed on the United States Center for Disease Control (CDC) website. CN is the active ingredient of Mace®, it is a riot control or tear agent, used by the military and law enforcement. It is also available to the general public in the U.S. The United States considers CN and its mixtures to be obsolete for military deployment. CN has a sharp, irritating odor and like OC it may be dissolved in a solvent and is available in many delivery systems.

The CDC has identified occupation exposure limits (OEL) for this chemical, as defined by NIOSH (National Institute for Occupational Safety and Health), OSHA (Occupational Safety and Health Administration), and ACGIH (American Conference of Governmental Industrial Hygienists), as follows:

1 NIOSH recommended exposure limit (REL): time weighted average (TWA): 0.3 mg/m3 (0.05 ppm)

2 OSHA permissible exposure limit (PEL): TWA 0.3 mg/m3 (0.05 ppm)

3 ACGIH threshold limit value (TLV): 0.32 mg/m3 (0.05 ppm)

4 NIOSH immediately dangerous to life and health (IDLH): 15 mg/m^3.

4.1.1 Data Gaps and Research Needs

Oleoresin Capsicum (OC)

The HERC report identified the following research needs related to developing a complete assessment as well as data gaps that do not relate to key research needs. While filling these latter data gaps may be of interest, it is highly unlikely that filling these data gaps would affect the results of the HERC[17].

- Comparative dose-response data for PAVA, capsaicin, and dihydrocapsaicin for key endpoints.
- Definition of effectiveness for small-droplet-size aerosols.
- Systematic statistically rigorous reporting system to measure effectiveness and adverse effects.
- Identification of a predictive dose metric for pressure injuries to the eye that applies to water droplets emitted from a variety of devices.
- Improved deposited dose estimates for the respiratory tract.
- Dose-response information for laryngospasm.
- Improved understanding of the relationship between the dose-response for bronchoconstriction in asthmatics and the dose-response for effectiveness in normal subjects and asthmatics.
- Information on the impact on effectiveness in individuals under the influence of drug or alcohol.
- Effects of repeated exposure, particularly on the respiratory tract.
- Improved estimate of the threshold for pulmonary effects, based on reliable dose-response data.
- Development of a self-contained pulse oxymeter that could be used on restrained people and under conditions of fogger exposure to monitor for adverse bronchoconstriction.

- Dose-response information on neurodevelopmental effects.
- Quantitative information on tachyphylaxis (reduced response after repeated exposure).
- Quantitative information on the impact of temperature and humidity on both the dose-response of capsaicinoids, and on exposure from OC and PAVA devices.
- Additional studies on the behavior and transport of droplets formed by OC devices.
- Data on the actual amounts of spray used to incapacitate individuals and the specific products used.
- Information on the composition of specific products.
- A survey of effectiveness for the different types of devices, including reporting of the conditions of use, which will allow for the determination of the influence of these conditions.
- A monitoring study of the distribution and persistence of aerosols following the use of foggers.
- Information on the potential for capsaicinoids to cause increased intraocular pressure and increased blood pressure in humans. This data could be obtained in controlled exposure studies. If such studies are conducted, it would also be of interest to collect data on hematology, clinical chemistry, and neuropsychological endpoints.
- Information on thresholds for ocular effects of solvents.
- Estimate of an SE 2 effect threshold for pulmonary effects of liquid aspiration.
- Toxicology studies: In vitro skin penetration; repeated inhalation exposure (up to subchronic) studies; developmental toxicology studies in two species (including monitoring of neurobehavioral and neuropathological endpoints); a two-generation reproduction study.

4.1.2 Standards

Less-lethal product standards could not be found for this specific group of products and only one test and measurement standard was found governing the capsaicinoid content. Industry standards concerned with efficacy and safety of these products are also notably missing.

Oleoresin Capsicum (OC)

To date there does not appear to be any industry standards for testing and evaluating the safety and effectiveness of OC sprays on humans. In Canada and the United States Capsaicin is regulated as a pesticide for use against animals.

The capsaicinoid content in a given solution is the determining factor of how hot a product will be, not the percentage of OC, or Scoville Heat Units (SHU's)[22]. The Major Capsaicinoid (MC) concentration quantification uses high-performance liquid chromatography (HPLC) using one of two methods; the America Spice Trade Association (ASTA) method 21.3, Pungency of Capsicums and their Oleoresins (HPLC method), which is virtually identical to AOAC 995.03 (The Association of Official Analytical Chemists).

In pepper sprays, the OC is combined with other products that hold the OC in solution and a propellant to discharge the solution. The area of concern in pepper sprays is to find the level that causes the desired effect, without risking permanent damage. It has been reported that increased levels of capsaicin can cause nerve damage, and possibly death of pain fibers. A concern most often overlooked is determining what these other products are. This concern is valid, considering that the other ingredients make up the majority (90-95%) of the product mixture. Often time, these mixtures are flammable, or contain ingredients that are listed as poisons, toxic, or cancer-causing[22].

In addition to the content analysis, label claim, and flammability analysis, another important parameter of concern is the aerosol particle size. Particle size is generally considered the critical factor that determines the region of deposition within the respiratory tract and is crucial to minimizing the possibility of undesirable and even harmful effects from an exposure to pepper spray[18].

However, some manufacturers[23] have adopted quality and operational standards from other industries and applied them to their products. These systems and component tests include quality control tests such as;

- Operation test
- Temperature cycle test
- One year time leakage test
- Discharge duration test
- Operating weight test
- Pressure vessel test
- Intermittent discharge test
- Gasket dependability test
- High temperature exposure test
- Hydrostatic pressure test

Applicable U.S. Federal Regulations include:

- 29 CFR 1910 Occupational safety and health standards
- 16 CFR 1500.41 Test for skin irritant
- 16 CFR 1500.45 Test method for determining flammability of contents of self-pressurized canisters
- AOAC 995.03 Oleoresin Capsicum assay
- 16 CFR 1500.130 Labeling of self-pressurized canisters
- 16 CFR 1500.42 Test for eye irritant
- 16 CFR 1500.3 Acute inhalation toxicity study

4.1.3 Associated Technologies and Weapon Characteristics

Irritant Agents

These agents are inflammatories and lachrymators that cause transient discomfort and eye closure. They require an extremely high concentration to be lethal and a very low concentration to be effective, so they have a high safety ratio. Their major purpose is to cause pain, burning, or discomfort on exposed mucous membranes and skin. These effects occur within a few seconds of exposure, but rarely persist more than tens of minutes after exposure has ended[15].

There are various Agents used, such as: Oleoresin Capsicum (OC), Ortho Chlorobenzalmalononitrile (CS), Chloroacetophenone (CN), and Diphenylarenamine (DM). All can be delivered as a fog, stream, foams/gels, or in powdered form. They are typically mixed in a solution and use some kind of propellant/carrier such as nitrogen or an encapsulated kinetic round. Oleoresin Capsicum (OC), and Ortho Chlorobenzalmalononitrile (CS) have largely replaced the other chemicals as these agents disperse quicker and have a more rapid onset. Oleoresin Capsicum (OC) is regarded as immediately effective and safer than other forms of tear gas or mace, such as CN and CS[24].

Oleoresin Capsicum (OC)

The Oleoresin Capsicum Dispensers (OC spray also known as pepper spray) are designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, assist in clearing spaces, entry control points, and crowd control. The Oleoresin Capsicum Dispensers are hand held dispensers providing variable range, single stream or area fog RCA against single or multiple subjects with irritant effects. Uses include crowd control and detainee operations. Multiple Services currently employ these devices[5].

6 Electrical Devices

6.1 Electrical Muscle Stimulation (EMS) Effects

4.1.4 Definition

Electrical muscle stimulation (EMS), also known as neuromuscular electrical stimulation (NMES) or electromyostimulation, is the elicitation of muscle contraction using electric impulses. The impulses are generated by a device and delivered through electrodes on the skin in direct proximity to the muscles to be stimulated. The impulses mimic the action potential coming from the central nervous system, causing the muscles to contract. In the United States, EMS devices used in the medical field are regulated by the U.S. Food and Drug Administration (FDA).

4.1.5 Device Description

The less-lethal industry has coined a term used to distinguish devices using EMS technology for less-lethal applications, such as; Electrical Stimulation Devices (ESD), but other synonyms exist (such as Conducted Energy Device, Electronic Control Device, Electromuscular Incapacitation Device, Electromuscular Disruption Device). These are devices that produce and deliver a less-lethal electrical shock to a subject, resulting in pain, involuntary muscle contraction, and incapacitation, depending on the device and its application. The shock can be produced by pulsed or direct electric current, affecting the target muscle signal paths and disturbing the body's nervous system. Conceivable undesired effects could include effects on the heart and interference with medical implants that utilize electricity, such as cardiac pacemakers. Electrical burns at the area of contact are possible[2].

This family of devices relies on extremely low electrical current to achieve compliance from targeted subjects. There are two effects of interest; pain and muscle tetany. The first is pain induced by electrical shock. This pain can produce compliance of a subject or sufficient distraction to enable an officer to disengage or use hand control techniques. As with any pain compliance tool, it is less effective against disturbed persons or those under the influence of alcohol or drugs. The second effect of interest is extreme (but temporary) muscle tetany – involuntary muscle convulsion. At the high frequencies (pulse repetition rates) of most of these devices (nominally 16-19 pulses per second), the muscle contractions appear as one smooth contraction. Unlike the "pain" effect, this muscle tetany appears to be universal across the human population in its effect. There are differences in how well particular devices achieve this tetany[15].

4.1.6 Delivery Modes

There are two delivery modes: tethered and drive-stun. The tethered systems fire two tethered darts that carry the electricity from the device to the subject individual. In drive-stun application, the EMD device is placed directly against the skin of the subject. In addition to differences among these devices in the physical delivery technique for the electrical charge, the electrical waveform

of each also differs, and so can the intended and unintended effects. For these reasons, comparison of effects data across weapons systems is complex.

4.1.7 Effects of Concern

The Air Force Research Laboratory (AFRL), in partnership with the Joint Non-lethal Weapons Directorate (JNLWD), conducts research to assist Non-lethal Weapon (NLW) Program Managers across the U.S. Department of Defense (DoD) in assessing effectiveness and risks of NLWs. This information is used to develop dose-response curves for the particular systems under review, identify data gaps and determine additional research requirements, and provide this information to those within the DoD who make policy and acquisition decisions. The Human Effects Center of Excellence (HECOE), located in the AFRL, conducts and coordinates the majority of human effectiveness testing for the JNLWD[25].

In this role, the HECOE coordinated a Human Effectiveness and Risk Characterization (HERC) report for Electromuscular Incapacitation (EMI) devices. Using available data, probability estimates as well as data gaps and uncertainties were characterized for intended and potential unintended effects of these types of devices. The risk characterization included two EMI devices manufactured by TASER International, the M26 and X26 TASERs®. Overall, the results support the conclusion that the M26 and X26 TASERs are generally effective for their intended use. These findings were used in the decision process of the Armed Services to procure Taser™ devices. The Canadian Police Research Centre review of conducted energy devices[26] also concluded that CEDs are effective law enforcement tools that are safe in the vast majority of cases.

Five effects of sufficient concern were identified in the HERC report and had adequate data to include in the quantitative dose response assessment[25]:

- Intended Effects (electrical) – Electromuscular incapacitation (EMI)
- Unintended Effects (dart related) – Ocular injury
- Unintended Effects (electrical) – Seizure, and ventricular fibrillation
- Other Effects – Fall injuries (lacerations, fracture, chipped teeth, concussion, etc.)

The HERC report did identify the possibility of several unintended effects, albeit with estimated low probabilities of occurrence, as follows;

- Unintended effects (dart related) – Blunt trauma, skin penetration, ocular injury, skin burns, blood vessel injury, and testicle injury.
- Unintended effects (electrical) – Discomfort, changes in blood pressure or heart rate, peripheral nerve injury, mechanical muscle injury, bone fracture, spontaneous abortion, acute respiratory impairment and failure, rhabdomyolysis, seizures, ventricular fibrillation, and cancer.

- Other effects – Fall related injuries, laser related eye injury, noise related injury, interaction with other NLW, and flammability/explosions. The last two are considered secondary effects and were not evaluated.

- Drive stun effects – Testicular torsion

Several data gaps were identified in the data evaluation. These gaps include the biological basis for TASER effects, appropriate dosimetry, and the impact of environmental and scenario-dependent variables on the induction of effects. Available laboratory data are too limited to adequately quantify all possible risks of ventricular fibrillation or seizures, particularly in susceptible populations. Limitations in the exposure and incidence data for some infrequent events, and the need to rely on a database of case reports compiled by manufacturers, was also noted. A research plan to begin further exploring these issues was developed and provided to the JNLWD. The JNLWP, as part of its research, development, test and engineering efforts, is supporting continued research into EMI to enable development of several technologies that may utilize this effect. Research includes epidemiological studies of medical outcomes from stun device use, investigating underlying mechanisms of action, modeling and measurements of current path in subjects, and understanding the health effects of EMI as a function of duration of exposure[25].

A separate health effects study was conducted at AFRL that focused on the physiological effects of EMI that would be used in other types of NLW. This study was looking at the effects of EMI use in different environments and configurations than the Taser™ device. This study's purpose was to evaluate changes in blood chemistry in swine after repeated exposures to EMI. Analyses of pig cardiac troponins T and I (as potential biomarkers of cardiac muscle damage) were performed by a commercial laboratory. It is unknown whether these preliminary data will be relevant, in terms of application to future clinical decisions regarding humans exposed to either EMI or TASERs. A paper detailing the study and the results is in final preparation for submission to a peer-reviewed journal. Until the article is accepted and published, additional details on the study will not be provided[25].

The Canadian Policy Research Centre also conducted a review of conducted energy devices[26] which focused on three areas; the medical safety of CED's, along with policy consideration, and analysis of the medical condition excited delirium. Only the TASER M26 & X26 were reviewed. The primary conclusions regarding the medical safety of CED's are as follows;

- Definitive research or evidence does not exist that implicates a causal relationship between the use of CEDs and death.

- Existing studies indicate that the risk of cardiac harm to subjects from a CED is very low.

- Excited Delirium (ED), although not a universally recognized medical condition, is gaining increasing acceptance as a main contributor to deaths proximal to CED use.

- The issue related to multiple CED applications and its impact on respiration, pH levels, and other associated physical effects, offers a plausible theory on the possible connection between deaths, CED use, and people exhibiting the symptoms of ED.

4.1.8 Safe Exposure Limits

Electromuscular Incapacitation (EMI) Injury

The available data on Electromuscular Incapacitation (EMI) used in the HERC report were from human experience, animal studies, as well as comparison to biological let-go thresholds. These data all suggest that when an electrical circuit is completed, muscle contraction will occur. Based on these data, TASER output is assumed to exceed the muscle contraction threshold in all cases where a circuit is established. Whether an induced EMD is fully or partially effective in controlling the exposed subject, however, depends on the location and distribution of the current path. The impact of dart placement on effectiveness is estimated based on observations from experienced users of the TASER and was integrated with hit probabilities in the risk characterization step of the analysis[25].

Ocular Injury

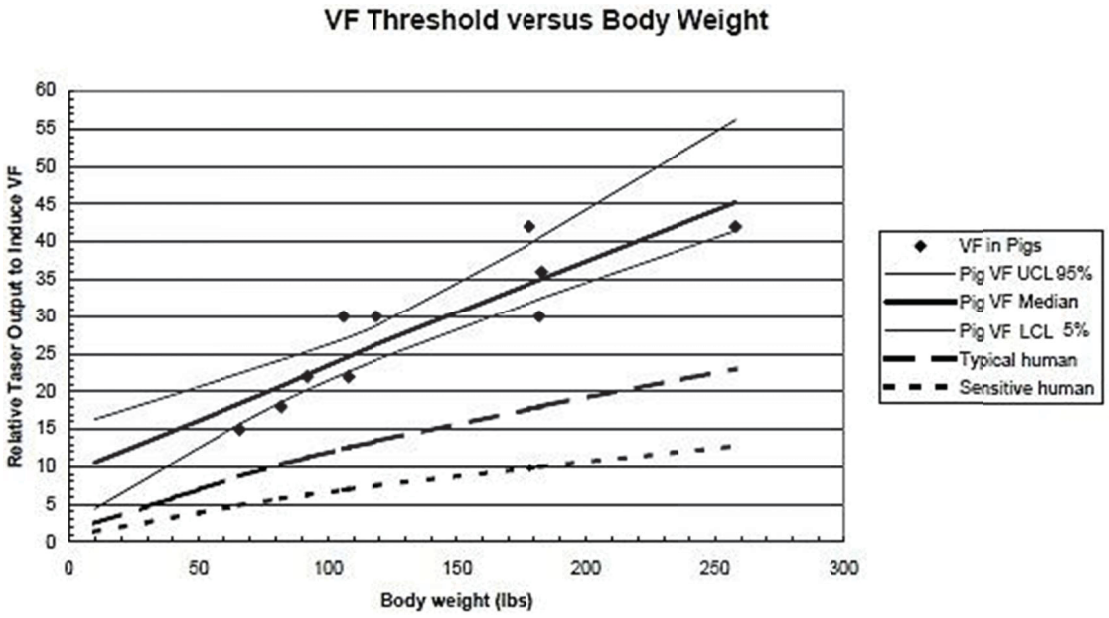
No dose-response data are available to calculate the probability of eye effects of different severities. Thus, any strike to the eye is considered a moderate to severe unintended effect. The risk characterization approach for ocular injury is a direct function of the probability of an eye strike from firing the device[25].

Seizures

Induction of seizures has not been tested experimentally for the M26 or X26 TASERs, although the TASER output is in the range of experimental seizure thresholds. A sensitivity analysis approach provides an upper bound estimate of seizure risk. Using this approach, any head strike that established a current path in the region of the brain is assumed to be sufficient to induce a seizure (i.e., exceed the seizure threshold). The hit probabilities for dart impacts in the head are used as the basis for the risk characterization of this effect[25].

Ventricular Fibrillation (VF)

A key effect of concern for which dose-response data are available is ventricular fibrillation (VF). Experimentally determined VF thresholds in pigs for differing TASER outputs are plotted against body weight. The resulting curve is extrapolated for use in assessing human dose-response with the use of uncertainty factors for experimental animal to human extrapolation and human variability. This analysis suggests that healthy adults and larger children would not be at significant risk of VF following exposure to the X26 TASER under normal operating conditions. However, due to assumptions made in selecting uncertainty factors and the absence of specific threshold information in young children, the elderly, individuals with underlying heart conditions, or individuals with concurrent drug use, it is not known whether there are highly sensitive individuals that could experience VF under normal EMI exposure conditions. The data are also limited with regard to extrapolating the results to the M26 TASER or future EMI waveforms, or for assessing the impact of different temporal patterns of exposure[25].



Fall Injuries

Published data on fall injuries rates are limited. However, TASER International field reports suggest that four moderately severe fall injuries have occurred in approximately 1600 or more deployments that resulted in a complete EMD. These data are consistent with expert judgments from TASER users in the law enforcement community. Based on the data and expert judgments, an injury rate of 1 in 500 (0.2%) fall events is used for the risk characterization[25].

4.1.9 Data Gaps and Research Needs

Several areas require further evaluation or data collection before a conclusion can be reached regarding potential effects or risks. Suggestions to address key uncertainties and data gaps include[25]:

- Develop a statistically rigorous database of field incidence exposures (target demographics, TASER International database)
- Develop a common metric for predicting physiological effects of exposure
- Determine the parameter of merit for EMI waveforms (total pulse charge, body current, net charge, charge in positive phase)
- Develop a dosimetry technique to compare existing and future EMI waveforms
- Determine the threshold for ventricular fibrillation/asystole

- Determine the threshold for seizures
- Determine the effect of scale (body size, mass, age, dart location/contact) on EMI response
- Develop a dose response for EMI intended effects (varying pulse amplitude, pulse duration, pulse form, inter-pulse interval)
- Determine the effect of drugs (e.g., ethanol, cocaine, phencyclidine) on the dose response to EMI
- Determine the effect of existing morbidity (e.g., cardiac arrhythmias, epilepsy) on the dose response to EMI
- Determine the effect of increasing the duration of stimulation
- Determine the effect of EMI on respiration
- Develop 3D impedance modeling
- Determine the impact of TASER stimuli on pregnancy & reproduction
- Examine applicability for novel applications such as remote or sensoractivated non-man-in-the-loop devices.

The CPRC report[26] also highlighted the fact that:

- A lack of scientifically tested, independently verified, and globally accepted CED safety parameters is problematic due to the reliance on manufacturer claim and leaves agencies ill-equipped to respond quickly to beneficial advances in technology.
- There is a lack of scientific information on death proximal to restraint.
- There is great interest in the physiological response to excited delirium.

4.1.10 Standards

Industry standards that identify the control parameters and thresholds for evaluating each effect of concern have yet to be developed. Currently the only testing protocols found are designed to ensure that the device is operating within approved operating parameters as defined by the manufacturer. An example would be the Canadian Police Research Centre's report on the testing of conducted energy weapons[27].

Standards from other industries might offer a way forward, such as those governing medical equipment, specifically nerve and muscle stimulators. The Canadian Standards association standard CAN/CSA-C22.2 No. 601.2.10-92 [28], which is essentially a copy of IEC 601.2.10-92, provides limitations on the output parameters for equipment intended for therapeutic applications

of never and muscle stimulation. However, such standards might be highly conservative with large safety factors and therefore might not induce the desired response.

4.1.11 Associated Technologies and Device Characteristics

TASER®

The X26 TASER® is designed to disable an individual. This technology has the potential to support multiple missions including: force protection, and crowd control.

The X26 TASER® is an electro-muscular incapacitation device that uses a nitrogen air cartridge propulsion system to launch two probes tethered to an electrically charged cartridge. Effective range is 0-35 feet, depending on cartridge type, penetrates up to two inches of clothing[5]

The X26 device has been highlight here based on its counter-personnel capabilities and status within the U.S. Department of Defense Joint Non-Lethal Weapons Program as current non-lethal weapons. Current non-lethal weapons are fielded and in use. Human effects assessments have been conducted to identify the technology's anticipated physiological responses and risk of significant injury to the subject, bystander, and operator. Concieveably the other Taser devices (M26, XREP, etc.) would also be suitable.

7 Multi-sensory Devices

7.1 Combined Effects

4.1.12 Definition

Combined effects include multi-sensory devices that affect more than one sensory modality simultaneously. There is an expectation that the effects will be at least additive and perhaps synergistic. Sensory overload is a possibility, leading to confusion and indecisiveness[2].

4.1.13 Device Description

Combined effect devices would include items such as: flash bang grenades (acoustic and optical diversionary device), multi-sensory distraction devices that contain a combination of payloads, and thermobaric compounds[2]. These are also referred to as Noise Flash Diversionary Devices (NFDDs). However, combined effects can include any combination of effects resulting from specific targeted sensory modalities, delivery, and exposure modes (e.g. blunt impact with chemical, blunt impact with electrical). All basic intended and unintended effects should be assessed.

4.1.14 Effects of Concern

The explosive force of these devices can cause major injuries if the device detonates in close proximity to a person. In addition to the explosive charge, which through its pressure wave may rupture tympanic membranes and possibly produce other primary blast injuries at distances closer than five feet, distraction devices contain powdered magnesium or aluminium, which burn brightly at high temperature and represent a significant ignition and burn injury hazard[29].

- Intended effects – temporarily impair hearing and vision
- Unintended effects – burns, soft tissue injuries, bony fractures, bleeding, pulmonary contusions, and GI tract injuries.
- Secondary injuries – falls and secondary projectiles propelled by blast.

4.1.15 Safe Exposure Limits

For NFDDs exposure limits are required for the following[30]:

- Illuminance and radiant flux (Flash) – Peak level (LUX) and total light energy (Joules) at varied ranges.
- Acoustic Sound (Noise) – Blast overpressure in air (bar), and peak sound (decibels).

- Functional delay (from pulled safety pin to first light)
- Functional Duration (burn time)
- Fragmentation due to function
- Collateral effects (fire start, propulsive movement, disruption of vicinity)

4.1.16 Standards

Product performance standards have not been established. However some manufactures have adopted industry standards related to safe functioning.

Occupational safety and health standards for noise and flash might be applicable, as defined in the previous sections covering Aural and Ocular effects. A subject matter expert might be required to determine the applicability of various guidelines and standards.

4.1.17 Associated Technologies and Device Characteristics

M-84 Flash Bang Grenade

The M-84 Flash Bang Grenade is designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, checkpoints, and assist in clearing spaces, crowd control, and entry control points.

The M-84 Flash Bang Grenade is a hand thrown flash bang that delivers a bright flash (optical effect) and loud bang (acoustic effect) against single or multiple subjects. Uses include crowd control and room clearing. Multiple Services currently employ this munition[5].

NICO BTV-1 Flash Bang Grenade

The NICO BTV-1 Flash Bang Grenade is designed to deny individuals access into/out of an area, move individuals through an area, and suppress individuals. This technology has the potential to support multiple missions including: force protection, assist in clearing spaces, checkpoints, crowd control, and entry control points.

The NICO BTV-1 Flash Bang Grenade is a hand thrown interim replacement for the MK-141 Flash Bang Grenade based on an urgent needs statement. Improvements prevent serious injury to personnel in the event of premature detonation of the grenade, provide 3-5 seconds of flash blindness, a lower pressure to reduce blast injury risk, and hand-safe capability with metal body and top and bottom venting. Multiple Services currently employ this device[5].

8 Technical Evaluations

The study of human effects of less-lethal devices is interdisciplinary, requiring expertise in the specific technology, the metrics and dosimetry of the energy utilized, and the relevant effects. The following table summarize the expertise needed to conduct a technical evaluation[2].

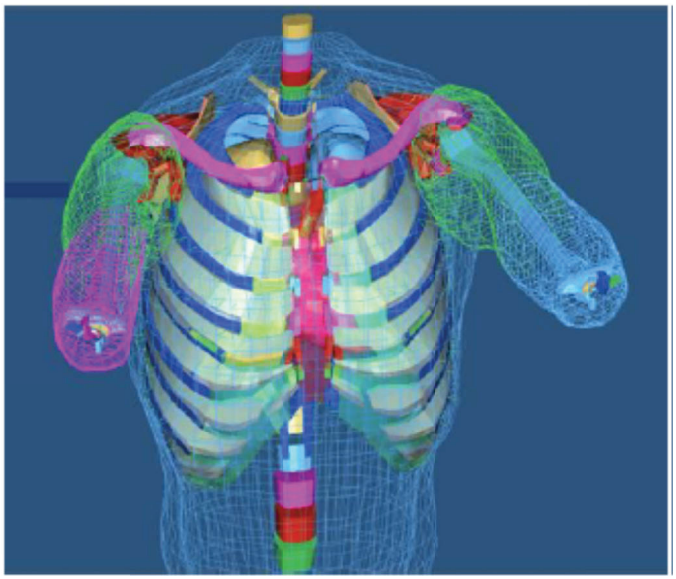
Table 2 Technical Expertise

Level of Organization	**Areas of Study**	**Possible Devices and Effects**	**Pressing Issues**
Cells	Toxicology, Cancer, Pathology	Chemicals used could be carcinogenic; lasers might damage retinal cells	Long-term health effects
Organs	Pathology, Anatomy	Blunt impact devices could damage organs; RF devices could burn skin	Damage to organs of sight or hearing; crippling body damage
Whole Organism	Physiology, Medicine	CEW's can incapacitate the whole person; likewise some gases	Damage to CNS function.
Individual behavior, motivation	Psychology	Behaviour may be modified to avoid unpleasantness, pain, or threat thereof	What is meant by incapacitation
Crowd Behaviour	Psychology	Devices may cause complex responses in crowds, from resignation and compliance to fear and panic	Predictive models for crowd response
Population Response	Sociology, Politics	Groups may develop incorrect beliefs about less-lethal devices and	Risk communication regarding safety, value, and ethics of

		acceptance could be threatened	devices

A classification scheme based on the NATO taxonomy with consideration given to the various effects (both intended and non-intended) of exposure to less-lethal devices is proposed. This will allow for the inclusion of new technologies as they become available. Since many of the major body regions and their related organs and systems have known injury thresholds this will help to identify proper test methods. This is in keeping with existing approaches to trauma prediction that include survivability-lethality-vulnerability (SVL) models to assess the interaction of conventional threats such as projectiles and fragments. The critical elements include models of the threat and delivery to the subject, their interaction with the anatomy and physiology, and injury outcome assessments based upon available injury criteria. Less-lethal devices include some unique threats not currently found in these models, but building upon and using these existing evaluation tools seems a natural evolution. Defence R&D Canada Valcartier have such models and expansion to threats other than ballistic penetration and blast is possible.

The United States Joint Non-Lethal Weapons Program has an advanced total body model that is used to characterize and assess less-lethal systems. Primary less-lethal human effects models include the Advanced Total Body Model (ATBM) for blunt impact injury assessment and the Optical Effects Model for broadband optical effects analysis. Less-lethal human effects models are developed from dose-response data generated by experimentation. Their Human Effects Modeling Analysis Program is a collection of detailed models that provide predictions for a range of human effects and permits a standardized and centralized approach for less-lethal device human effects assessment.



9 Risk Characterization Framework

The Joint Non-Lethal Weapons Directorate (JNLWD) Human Effects Center of Excellence (HECOE) developed a Human Effectiveness and Risk Characterization (HERC) framework to evaluate non-lethal weapons. The objective is to assist decision and policy makers in determining the technical feasibility, likely effectiveness, safe operational use, and policy acceptability of NLW's.

The method considers the risk of unintended effects to the targets, users, and bystanders, as well as weapon effectiveness, uncertainties, and limits of human effects models. This process is consistent with the National Academies of Sciences and the Society for Risk Analysis recommendations and standards. The risk characterization framework utilizes the four steps of hazard (effects) identification, dose-response assessment, exposure assessment, and risk characterization initially developed for the evaluation of chemical substances. The term "dose" is used in a generic sense to convey a quantitative measure of the substances or forces released by a non-lethal weapon. The HERC reports are organised according to these four steps. Three workshops consisting of subject matter experts and risk assessment experts are typically held as part of the process. The first is a data sharing workshop that identifies all possible sources of relevant data and determines insufficiencies in effectively evaluating the NLW. The second is a peer consultation workshop that outlines potential data gaps, identifies additional sources of data, and provides feedback on preliminary strategies for completing dose-response and exposure assessments. The third workshop is an independent external review panel that submits comments and recommendations that are incorporated into the final HERC document.

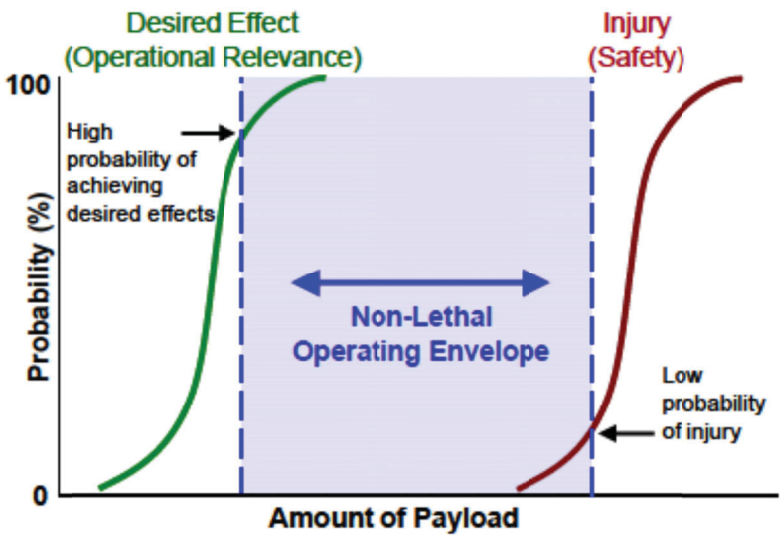
The HECOE is also the central repository of human effects data and maintains extensive references for the full gamut of technologies used in NLW developments. However, public access to this data seems limited.

9.1 Hazard Effects Identification

The first phase in the HERC framework is to identify all possible effects of the weapon, both intended and unintended. The next step is to combine all the unintended effects in a way that allows easy comparison with the intended effects. One approach is to combine all of the effects of equal severity for a combined effect. Another approach would be to select a single critical effect to establish a benchmark to compare with other levels of exposure (dose). The quantitative data on the combined effects, or the critical effect, helps to develop the dose-response curves.

9.2 Dose-Response

The second phase of the HERC framework refers to the process of evaluating information on the magnitude or intensity of the dose required to produce the physiological effect or behavioral response desired.

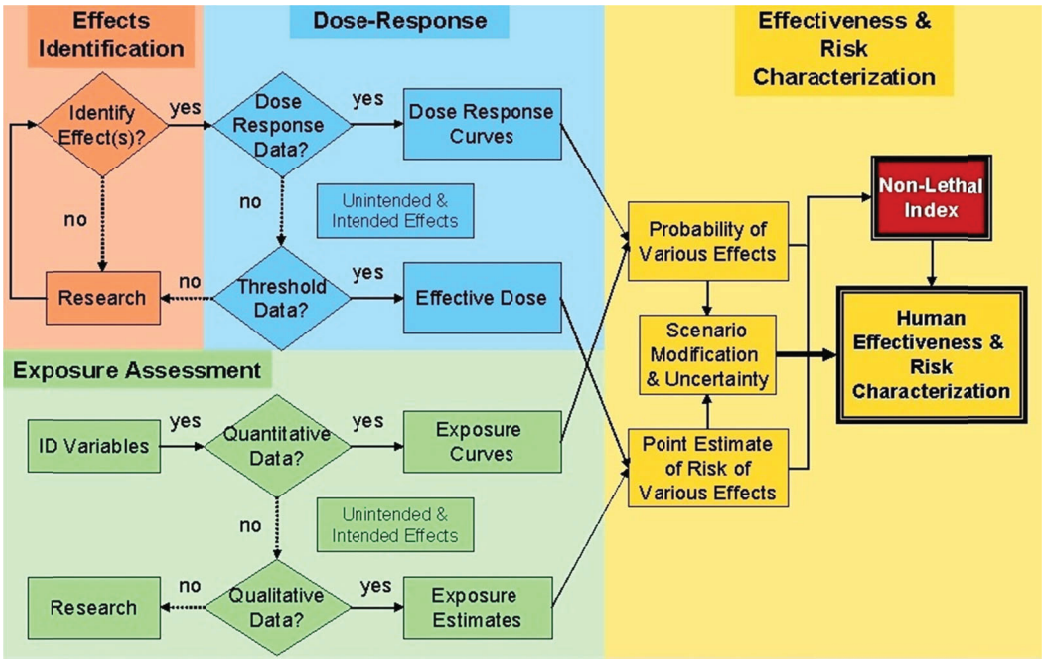


9.3 Exposure Assessment

The goal of this third phase is to define the interaction between the technology or device and the user, the subject, and bystanders. This phase specifies the information necessary to characterize the intended and unintended effects using the dose metrics and the response information from the previous phases. This phase begins with the specific devices included in the assessment and the use of the devices. The use is defined in terms of one or more concepts of employment (COE). The COE defines the following elements in the use of a non-lethal weapon; the nature of the user, the conditions under which the NLW is used, the subject individuals, and the tactical goals for the use.

9.4 Risk Characterization

In this phase the probability of occurrence is determined for various intended and unintended effects. Once this is complete a Monte Carlo model is used to estimate the frequency of the occurrence of intended and unintended effects. Probabilistic and point estimate methods are suggested as two examples of risk characterization metrics.



9.5 Standards Framework

While there is much discussion about less-lethal research, field reports, policy, and training issues; there seems to be little in the way of product performance and safety standards for in-service items. However, in addition the JNLWD HERC assessments, the National Institute of Justice (NIJ) is working on a less-lethal devices standards framework for less-lethal product performance and safety standards (Figure 5 LLD Standards Framework).

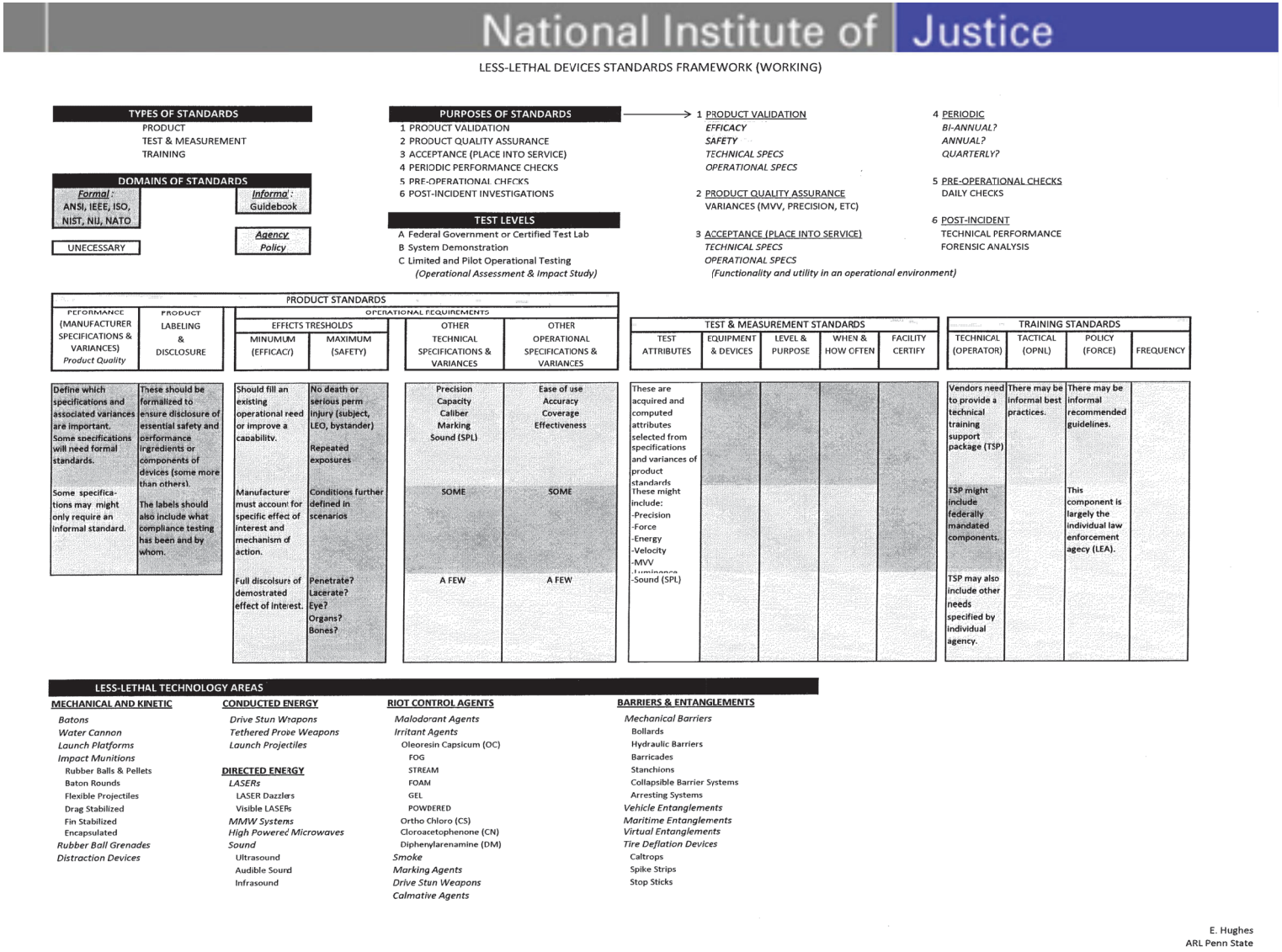


Figure 5 LLD Standards Framework

10 Taxonomy (Counter Personnel)

A classification scheme based on the NATO taxonomy with consideration given to the various effects of exposure to less-lethal devices is proposed. This will allow for the inclusion of new technologies as they become available. A summary of the standards, or lack thereof, has also been included to help identify gaps to be filled and to assists with the approval process.

Product standards, as previously discussed, would consist of performance requirements for the device manufacturers to follow. Test and measurement standards would focus on the critical performance aspects required for product certification and evaluation. Safety standards are meant to address permissible exposure limits for health and safety.

In the absence of product safety and performance standards it would be prudent to insist that whenever a canister or a projectile is launched, or debris are expected when deploying a NLW, blunt impact and penetration tests have to be performed.

Table 3 Taxonomy (Counter Personnel)

Technology	Class	Effects of Concern	Standards	
Electro-magnetic	Electro-muscular	Intended Effects (electrical) – Electromuscular incapacitation (EMI) Unintended Effects (dart related) – Ocular injury Unintended Effects (electrical) – Seizure, and ventricular fibrillation	Product	None
			Test	None
			Safety	None
	Optical	Intended Effects (Ocular) - distract Unintended (Ocular) - Eye and skin damage due to laser radiation	Product	None
			Test	• ANSI Z136.1 Safe use of lasers
			Safety	• Occupational safety and health standards
Chemical	Irritants/Riot Control Agents	Intended – eye, and respiratory irritation Unintended – pressure injury to the eye, bronchospasm, pulmonary effects,	Product	None
			Test	• 16 CFR 1500.41 Test for skin irritant, • 16 CFR 1500.45 Test method for determining flammability of contents of self-pressurized canisters,

		aspiration, and flammability		• AOAC 995.03 Oleoresin Capsicum assay, • 16 CFR 1500.130 Labeling of self-pressurized canisters, • 16 CFR 1500.42 Test for eye irritant, • 16 CFR 1500.3 Acute inhalation toxicity study
			Safety	• 29 CFR 1910 Occupational safety and health standards
Acoustic	Directed Energy	Intended – Pain Unintended - Noise induced hearing loss	Product	None
			Test	None
			Safety	• MIL-STD-1474D Noise Limits, • Occupational Health and Safety Administration (OSHA), • National Institute for Occupational Safety and Health (NIOSH), • Canadian Centre for Occupational Health and Safety (CCOHS)
Mechanical Kinetic	Impact Munitions	Intended – Pain Unintended – Head and face impacts: Skull and facial fractures and brain hematomas Thoracic; rib fracture, heart concussion and contusion and lung contusion	Product	None
			Test	None
			Safety	None
Combined (Multi-Sensory)		For multi-sensory effects, all basic intended and unintended effects should be assessed.	Product	None
			Test	None
			Safety	None

11 Conclusions

While there is much emphasis on policy and procedure, and much discussion about human effects there are not any less-lethal product specific performance and safety standards for industry to follow.

Some occupational exposure standards exist for a particular agent being used, as for many types of noise, radiation and chemicals, and these standards should be followed when possible. However, such standards are highly conservative with large safety factors and therefore might not induce the desired response. Other agents and technologies are without guidance on safe limits.

Some device manufacturers have adopted component and system tests, as well as technical standards, regulations, and guidelines from other industries and application. The implementation of these is at the discretion of the manufacturer and is not consistent throughout the industry, creating an environment of buyer beware. In the absence of industry regulations and standards strong product claims can be made without evidence or references.

In general, injury thresholds seem to be known for many of the major body regions and their related organs and systems. However, despite the human effects data collected so far, defining the threshold between no-response, the desired response, and injury is not well defined. Combining this knowledge with device effectiveness and risk assessment methodology to create product performance and safety standards for less-lethal devices seems to be stalled in the research stage.

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Biokinetics was tasked by DRDC Valcartier as part of the CEWSI (Conductive Energy Weapon Strategic Initiative) to define a classification schema based on available information that can be used as part of an approval process to ensure that technologies to be approved are assessed using proper regulations and test protocols. This was achieved by conducting a review of source material that came from previous DRDC contracts, NATO and TTCP panel reports, as well as the internet. Results indicate that despite much research and discussion about device effectiveness, evaluation methodologies, and studies of human effects; there are not any product standards for less-lethal devices.

If occupational exposure standards exist for the particular agent being used, as they do for many types of noise, radiation and chemicals, then these standards should be followed when possible. However, such standards are highly conservative with large safety factors and therefore might not induce the desired response. In general, injury thresholds seem to be known for many of the major body regions and their related organs and systems. Combining this knowledge with device effectiveness and risk assessment methodology to create product performance and safety standards for less-lethal devices seems stalled in the research stage.

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