LROI SYSTEM FUNCTIONAL DESCRIPTIONS

(INITIAL)

1.0 Introduction

This document provides a description of the Long Range Optical Interrupter (LROI) system, detailing initial functions and rationale, physics-based boundaries or practical limits that potentially constrain practical development of functions, the technology maturity level for key technologies required, and what is required to advance key technologies currently assessed as immature.

2.0 Primary Purpose of LROI

LROI is a non-lethal weapon whose primary purpose is to project a bright beam of light onto an advancing individual, group, or craft. The spot of light produced is expected to increase in intensity as the contact /target of interest's (COI/TOI) range to the LROI system decreases. The projected spot is required to be of sufficient intensity to "hail" or "warn" targeted personnel or craft operators. Should the COI/TOI not respond to the Hail/Warn illumination, a higher intensity irradiance to "suppress" can be initiated. The Suppress irradiance is expected to cause a COI/TOI behavioral response.

Full understanding of the terms "hail", "warn", and "suppress" is critical to establishing LROI performance criteria. The following definitions apply:

- **Hail** (derived from Merriam-Webster): call or signal over a distance to attract attention or recognition
- **Warn** (derived from Merriam-Webster): unambiguous notification or alert of pending hazard or danger
- **Suppress** (Joint Non-Lethal Weapon Directorate (JNLWD) Initial Capability Document (ICD) for Counter-Personnel (CP), Apr 2009): ability to distract, disorient, and/or degrade an individual's ability to perform a specified action

Note: Numerous JNLWD and other documents regularly use the terms "hail" and "warn", however the military definitions for these terms are not provided. The above definitions for Hail and Warn will be used as preliminary military definitions for the LROI development until formal definitions are established.

3.0 Functional Development and Requirements Basis

The functions described in this document are derived from user defined requirements, consistent with their operational environments, physics and technology constraints, and pertinent human effects and susceptibilities. The need for specific operational functions was identified by logically combining information from these sources. The resulting Requirements and Limitations are shown in Table 1 below:

Table 1 - Requirements/Limitations

Requirement/Limitation		Quantity	Source
Hail/Warn	Max Range	3000 m	UONS
	Min Range	500 m	Current fielded system's effective range
	Spot Size	3 m	Nom. Vehicle Width (2m +50%)

Requirement/Limitation		Quantity	Source
	Spot Irradiance	≥100 µW/cm^2	ANSI Z136.6/HECOE
Suppress	Max Range	1800 m	User defined
	Min Range	500 m	Exceed current fielded system's effective range
	Spot Irradiance	<2.55 mW/cm^2	ANSI Z136.6/HECOE
Wavelength	Visible	≥495 nm	Do not use blue (LSRB advisory)
Laser Output Power Upper Limit	Waste heat removal complexity	~20W	Initial survey of field portable laser based military systems
Eye Safety	Incidental	NOHD	UONS
	Aided Eye	OA Range	UONS
Risk of Significant Injury (RSI)	Aggregate Measure of Overall Risk to Human Targets	1.0 %	Achieving desired NL effect without causing permanent injury (Health Care Capability/Limited First Responder Criteria) AFRL RH-BR-TR-2010
Weight/Volume	Expeditionary/ Man-portable	<35 lbs	User defined
Power	Expeditionary	Self contained	User defined
Environmental Compatibility	Maritime	Survivable/ Inter-operable	MIL-STD-810G/461F

4.0 LROI Beam Features

The LROI light beam will project symmetrical spots of irradiance onto incoming targets. The projected spot should consist of variable/selectable irradiances to achieve two levels of effect; Hail/Warn irradiance, and Suppress irradiance. The potential features of the LROI are described in the following subsections.

4.1 Establishing Militarily Useful Spot Sizes

A cursory examination of expected or potential LROI targets was conducted to establish the likely range of illumination spot diameters. The preliminary conclusion was that targets as small as a human face (~0.3m) and as large as the frontal cross-section of a vehicle or small boat (~3m) would satisfactorily define the full range of probable LROI targets. It was further concluded that spot diameters that exactly fit the nominal dimensions of these targets would unnecessarily force precision in LROI beam pointing, tracking, and stabilization requirements, potentially increasing system complexity and cost. To accommodate this variability, engineering margins (~50%) were applied to expand final spot diameters. A militarily useful spot diameter range of 0.33m (face) to 3 - 4m (vehicles, craft) is initially proposed.

4.2 Hail/Warn

- **Purpose**: The Hail/Warn beam is to project a spot of light with sufficient irradiance such that it cannot be casually overlooked or ignored. From the perspective of those being illuminated, the Hail/Warn beam will present a bright source of light of such intensity that it will assert an undeniable visual dominance over all other scene content. It is expected that illuminated individuals will react in some discernable fashion to application of the LROI Hail/Warn beam. Should the Hail/Warn illumination fail to discourage approach, the LROI operator will have the option of employing the higher irradiance Suppress illumination.

- **Performance Attributes**: The LROI will Hail/Warn over ranges of 500m – 3000m. These ranges address a documented capability gap. The Hail/Warn spot requires a diameter of at least 3m to assure full illumination of the frontal cross-section of nominally sized craft (ground vehicles, small boats). This spot size ensures all personnel aboard or immediately near the craft is illuminated, and assures adequate coverage for dismounted individuals. Hail/Warn spot irradiance must be at or above 100 $\mu W/cm^2$ to assure the LROI will dominate over ambient illumination in day and night conditions.
- **Technology Assessment**: Projection of 3m diameter spots with 100 $\mu W/cm^2$ irradiances at ranges of 500m to 3000m is achievable with COTS/NDI technologies.

4.3 Suppress

- **Purpose**: The Suppress beam will project a spot of light with sufficient irradiance to degrade the vision of individuals being illuminated. Degradation may take two forms:
  - Glare obscuration of the area in and around the LROI if the targeted individuals are looking into the LROI beam
  - Excessively bright illumination in the immediate area around the target such that targeted individuals find it difficult to recognize or interact with their surroundings

  The first effect is caused by light scattering within the targeted individual's eyes. When looking into a low-irradiance laser beam, an individual will experience an obscuration of vision over the angular extent of the laser's aperture. With increasing irradiance, scatter within the individual's eye will increase, obscuring a progressively larger portion of their vision beyond the laser aperture. This glare obscuration can range in effective angle from <1° to >20° of the eye's field of view, up to the Maximum Permissible Exposure (MPE).

  The second effect is caused by intense monochromatic flood illumination in the immediate area surrounding the targeted individual, causing visual disorientation. This effect is more pronounced at shorter wavelengths (e.g. green at 532 nm) and if the illumination source is spectrally narrow and coherent (i.e. from a laser). It has been studied and demonstrated in field tests but has not been properly characterized under formal human effects testing.

- **Performance Attributes**: The LROI system is expected to project Suppress illumination spot over ranges of 500m - 1800m. Irradiance to achieve the Suppress effects stated above should be maintained at less than the 2.55 mW/cm^2 eye safety MPE using an acceptable safety buffer. Although spot diameter of 3m are desired, current laser technologies for portable systems may dictate a practical limit of 1m diameter for military applications.
- **Technology Assessment**: Generation of illumination spots with irradiances up to 2.55 mW/cm^2 requires significant source optical powers. The primary impediment to higher laser power is the need for cooling systems to dispose of waste heat in extreme operational environments.

  It should be noted that Suppress effectiveness will not be as dramatic in daylight due to competition with daytime background illumination.

4.4 Fixed versus Variable Beam Width

- **Purpose**: In order to achieve the specific spot sizes defined above at the required Hail/Warn and Suppress ranges, the LROI system may require dynamically variable beam divergence. Ideally, the LROI system would automatically vary the beam divergence such that the illumination spot would correspond to target range. As moving targets close, the reduction in spot diameter would cause the spot irradiance to increase from Hail/Warn to Suppress levels.
- **Performance Attributes**: Optical systems designed to produce variable beam divergences have practical and physical performance limits. For LROI, it is estimated that a wide to narrow beam divergence ratio of 10 should be adequate and attainable. The narrowest beam divergence needed is driven by the Suppress 1m spot at 1800m (or 0.55 mrad). The widest beam divergence is driven by the Hail/Warn 3m spot at 500m (or 6.0 mrad). Therefore, a 10X zoom applied for variable beam divergence should satisfy the operational need.
- **Technology Assessment**: Variable beam divergence optics is similar in design to telephoto zoom lenses. Such systems are judged by the ratio of the largest to smallest beam divergence that these optical systems can achieve. The best high quality zoom optics achieves 3X-4X zoom ratios while still retaining excellent image quality. Fortunately, such high quality optical performance is not required for LROI beam projection. Lower optical quality beam divergence optics can achieve zoom ratios of up to 10X. Existing zoom optics may not be adequate to meet LROI performance.

4.5 Variable Output Power

- **Purpose**: In order to achieve both Hail/Warn and Suppress irradiances at the ranges detailed above while ensuring eye safety for intended targets and individuals accidentally exposed, the LROI system will require dynamically variable output beam power.
- **Performance Attributes**: Output powers from ~7 W to ~20 W are estimated to meet LROI spot irradiance for the performance ranges specified. These values are derived from the threshold Suppress 1m spot at 1800m and the Hail/Warn 3m spot at 500m.
- **Technology Assessment**: A variety of methods exist to adjust output power of laser sources, with each having advantages and disadvantages that must be balanced against LROI performance. These methods range from varying input electrical power to the source, to varying the output from a combination of multiple smaller sources. Further investigation and analysis of current technologies is required to determine the best approach to meet LROI parameters.

4.6 Range Detection & Safety Interlock

- **Purpose**: In projecting Hail/Warn and Suppress illumination at the required ranges, the LROI system's beams will likely exceed MPE at closer ranges. An automated and reliable means to safeguard incidental eye damage to own-force or non-combatants will be required at close ranges. This will require a source to target ranging capability in order for LROI to rapidly determine the range to objects entering the LROI beam. Encroachment into the LROI beam within the NOHD must result in automatic reduction of beam output power.
- **Performance Attributes**: A ranging capability is required to properly support LROI eye safety requirements. This capability shall be consistent with defined LROI operational ranges.

- **Technology Assessment**: Current range finding technologies are mature and can be integrated with minimal modification.

4.7 Magnifying Optics Detection (MOD)

- **Purpose**: A persistent concern in using the LROI system against approaching contacts of interest/targets of interest (COI/TOI) is the possibility that these individuals will employ magnifying optics (e.g. binoculars, rifle scopes, camera sights) to view the origin of the LROI beam. This would result in an increased power entering the individual's eye, potentially exceeding the MPE. Therefore, it is desirable to detect the use of magnifying optics by the target to either alert the operator and/or automatically reduce LROI beam power until an assessment of the target can be made.
- **Performance Attributes**: MOD is a commonly known effect where focusing optical systems tend to retro-reflect incoming light toward its source. It is preferred that LROI provide a means to detect the use of magnifying optics to alert the operator and adjust LROI beam output power.
- **Technology Assessment**: Numerous approaches and techniques (counter-sniper, periscope detection) have been explored and demonstrated with respect to MOD. However, exploration into COTS/NDI technology solutions for integration into LROI requires further investigation.

4.8 Optical Sighting

- **Purpose**: The system operator requires the means to direct the LROI beam and verify, view, and observe targets.
- **Performance Attributes**: An optical sighting system aligned with the LROI beam is required. A minimum magnification of 10X is preferred. Magnifications should take into account trade-offs between the level of detail provided and situational awareness needs. Further they should take into account the loss of resolution that can occur during LROI angular slewing activities, a factor that grows more pronounced at higher magnifications.
- **Technology Assessment**: Achieving a balance between target detail, situational awareness, and angular slew resolution performance loss may require a solution involving zoom or selectable magnification settings. The need for an active imaging system to provide low light level or infrared imaging optical sight capability in support of day/night operations has not been established. Trade-off analysis s between powered, complex sight solutions and simple optical telescopes is necessary. Optical sight solutions stated above exist in commercially available technologies that will satisfactorily address the need with minimal modification.

4.9 Beam Power Environmental Compensation

- **Purpose**: LROI system output beam power will decrease with range due to atmospheric attenuation effects. There is a desire for the LROI system to compensate for atmospheric attenuation effects to assure that the proper beam spot irradiance at the target. For the purposes of LROI, this capability is being referred to as, "beam power environmental compensation."

  The amount of atmospheric attenuation affecting the LROI beam is highly dependent on local weather conditions, local environmental effects, and, at times, the direction the beam is

pointed. An atmospheric measurement capability will be required to estimate the effects on beam power loss and calculate beam power adjustment.

- **Performance Attributes**: Any attenuation measurement capability devised for LROI will require sufficient accuracy to assure automatic adjustment to the Suppress spot irradiances in order to avoid exceeding eye damage limits. Attenuation measurement range must cover LROI operational ranges. Because directional variance can occur with attenuation measurements, the attenuation measurement capability will, at a minimum, measure along the LROI output beam path. Measurement sample rates should be sufficient to detect weather changes that effect LROI performance and insure accurate beam output power adjustment.
- **Technology Assessment**: There are a number of bi-static and mono-static measurement solutions for gauging atmospheric attenuation along a path. However, commercially available technologies only provide accurate environmental information local to the point of origin (source) and cannot provide accurate measurements for remote targets (COI/TOIs) at a distance.

4.10 Beam Pointing, Target Tracking, and Stabilization

- **Purpose**: The LROI system will need the capability to point and maintain its output beam on approaching targets. Expected Hail/Warn and Suppress spot sizes and ranges provided in earlier sections indicate that the LROI output beam width may be as narrow as 0.55 mrad. Beam pointing and stabilization will need to maintain illumination spots, including small spots at distant ranges, on moving targets.
- **Performance Attributes**: Beam pointing, target tracking, and stabilization is needed to assure that the illumination spot is maintained on the COI/TOI.
- **Technology Assessment**: COTS/NDI solutions are available to support beam pointing, target tracking, and stabilization. Integration of existing capabilities for LROI requires further exploration.

4.11 System Control and Display

- **Purpose**: The LROI system requires integrated control and display. This provides the operator the means to monitor and control all aspects of LROI operations.
- **Performance Attributes**: The system control and display capability may consist of the following:
  - User Inputs - On/Off, Hail/Warn or Suppress Select, Execute BIT (built-in test), Display Controls (brightness)
  - User Outputs - Target Image, Target Range/Velocity, NOHD Interrupt Warning, Optical Aide ID Warning, BIT Status/Warnings
  - COI/TOI range data
  - Range processing, derived COI/TOI velocity processing
  - MOD Alerts and Displays
  - Integrated MOD processing
  - Conduct BIT (Built In Test: power, internal temperature, subcomponent status)
  - Output BIT results
  - Beam divergence control/status

  - Beam output power control/status
  - NOHD safety controls
  - Data logging/recording output
- **Technology Assessment**: Technologies are mature. A trade-off analysis is required to determine the most cost-effective design consistent to meet performance while maintaining an expeditionary footprint.

4.12 Expeditionary Power

- **Purpose**: The expeditionary version of LROI must be man-portable. This places physical constraints on LROI size, weight, and packaging. These constraints will drive power consumption/management and logistic footprint.
- **Performance Attributes**: Expeditionary power is focused on providing a reliable source of power for LROI that is compatible with the expeditionary warfare operating environment while maintaining environmental and system safety requirements.
- **Technology Assessment**: Existing on/off board power sources are available. Trade-off analysis is required to determine power consumption associated with operational modes and states. The most cost-effective design consistent with performance while maintaining an expeditionary footprint is the goal. Identification of available lightweight, small footprint, high power density, and environmentally compatible power sources for utilization and adaption is needed.