Performing Counter-High Energy Laser Evasive Tactics

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ABSTRACT
The purpose of this article is to present several physics-based mathematical probabilistic models for Counter Directed Energy Weapon operational planning. The scenario analyzed is that of a surge of friendly Blue aircraft closing on a single High Energy Laser. The surge is a mixture of Blue active platforms, and Blue low-value decoys. Blue is targetable for a finite time. Blue response/measures of effectiveness quantify the survivability of Blue Actives. Red response is the number of Blues killed. Red defense tactics trade off longer engagement times, resulting in higher probabilities of kill, and the number of Blues it can engage in the finite time.

Keywords: Counter Directed Energy Weapon, Fixed Total Engagement Time, High-Energy Laser, Multiple Targets, Systematically Varying Probability of Kill

INTRODUCTION
Directed energy weapons (DEWs) have attracted attention for many years; cf. Florig, 1998; Defense Science Board, 2001; Defense Science Board, 2007. DEWs have the potential to greatly influence the conduct of warfare. We will restrict our attention to high-energy lasers (HELs) that can attack targets that are within line of sight, provided not impeded by adverse atmospherics. The HEL is an aimed fire weapon and can engage one target at a time; the target must first be acquired and then the HEL aims a laser beam at the target for a dwell time. The dwell time is the time the laser beam is focused on the target. The target is neutralized (killed) by the heat generated by the laser beam on the target during the dwell time; longer dwell times result in higher kill probabilities. The length of a dwell time needed to achieve a particular probability of kill depends on the distance to the target. Dwell times can be on the order of one to five seconds. Thus, accounting for acquisition and dwell times, there is a maximum number of targets that the HEL can engage in a specified time.

The probability of neutralizing a target is a function of a) the power “fluence” of the HEL at the target (typically measured in joules/square centimeter); b) the target’s photonic energy absorption (reflection or transmission); c) the weapon’s dwell time on the target (often...
measured in seconds); d) transmission efficiency through the atmosphere (which include such effects as absorption and lensing); (Morrison, 2010; Colson, 2010; Nielsen, 1994; Friedman & Miller, 2004). Certain areas of the target are more vulnerable to the effects of the laser beam. The probability of killing a target is influenced by the distance the target is from the HEL and the dwell time as well as the properties of the target and atmospheric conditions. The killing of the target may not result in the immediate destruction of the platform, but rather damage to electronics or sensors. Thus battle damage assessment (whether or not the target has been killed) may not be instantaneous.

In our first section, a scenario is presented in which several Unmanned Aerial Systems (UASs) (a swarm) fly through a region containing one HEL. The swarm is comprised of low-value decoys and non-decoy (Active) UASs. The swarm is subject to Red attack for a specified finite time. In the second section we present a physics-based model for the probability a target acquired at distance \( z \) is killed by the HEL. Approximations to the probability of kill are also presented. In the third and fourth sections we investigate the number of decoys needed in the swarm so that at least one active UAS survives with a specified probability. In the third section the Red tactic is to spend a constant dwell time on each engaged Blue target; thus the probability of kill increases as the target moves towards the HEL. In the fourth section the Red tactic is to choose dwell times so that there is a constant probability of kill for each engaged target; the dwell time decreases as the target moves towards the HEL.

Our analysis shows the effect of the addition of increasingly many Blue decoys on reducing risk to those Blues that are not decoys (Active). Also illustrated is the Red tradeoff between probability of kill and the number of Blues it can engage.

In this paper, the HEL is not subject to attrition. In Barkdoll, Gaver, Glazebrook, Jacobs, and Posadas (2002) and Glazebrook, Kirkbride, Mitchell, Gaver, and Jacobs (2007) related models are considered in which the longer the HEL is lasing targets, the more likely the position of the HEL can be estimated using sensors and the HEL neutralized by standoff Blue weapons. We postpone this consideration for the present.

### THE SCENARIO

Blue Unmanned Aerial Systems (UASs) must travel through a region to conduct intelligence, surveillance, reconnaissance (ISR) missions. Blue suspects that Red may have one HEL in the region but does not know its location. To counter the possible HEL, a *surge or swarm*, \( S \), of Blue UASs comes nearly simultaneously into the region. There are \( A \) Blue actives and \( C \) low-replacement-value decoys in the swarm. Suppose the \( \bar{B} = A + C \) Blue UASs present themselves in an equally accessible and indistinguishable way to the Red HEL. The entire surge/swarm, \( S \), is subject to attrition for a time \( T \) in the Red-defended region. Time in region is presently taken as fixed, and all Blues are vulnerable during this time. Blue (B) chooses the number of Active Blues and decoys in the swarm so that the probability at least one Active Blue survives meets a specified threshold.

An initial defensive attempt by Red is to acquire and “shoot at” a random subset of \( \bar{B} \) Blues: the Red engaging a single Blue at a time. Assume (initially) that with probability \( p_A = A / (A + C) \) Red picks an Active Blue from the surge, otherwise picking a decoy. Red initially picks at random without discrimination, which may be Red-pessimistic. For subsequent engagements, Red picks at random from those not yet engaged.

Each Red-on-Blue engagement begins with Red acquiring a target which takes an acquisition time \( T_a \), followed by a HEL dwell time \( T_d \) during which time the target is lased. The time to engage a target \( T_E = T_a + T_d \). We assume successive acquisition and dwell times are independent positive random variables; it will often be true that \( T_d \) will be a constant decision variable selected by R to minimize B’s
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