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## **Implementing a Probabilistic Line of Sight in EASEE (Environmental Awareness for Sensor and Emitter Employment)**

Michael T. Ekegren and Kenneth K. Yamamoto

May 2015



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# **Implementing a Probabilistic Line of Sight in EASEE (Environmental Awareness for Sensor and Emitter Employment)**

Michael T. Ekegren and Kenneth K. Yamamoto

*Cold Regions Research and Engineering Laboratory (CRREL)*  
*U.S. Army Engineer Research and Development Center (ERDC)*  
*72 Lyme Road*  
*Hanover, NH 03755*

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## Abstract

This report covers the effort to better represent the effects of natural and man-made surface features on visibility by incorporating probabilistic methods into a line-of-sight tool within the Environmental Awareness for Sensor and Emitter Employment (EASEE) software package. Traditional line-of-sight methods are strictly binary: the possibility of seeing from one point to another is either yes or no without a consideration for what is in-between. The major issue that hinders traditional line-of-sight tools is that they use only one elevation model in their calculations. A single elevation model oversimplifies the complexity of the physical environment, creating unrealistic representations of both the Earth's surface and visibility. While computationally fast, this type of tool results in output that is often conceptually flawed. The developed probabilistic line-of-sight algorithm corrects for this issue by incorporating multiple elevation models and land cover data to better represent and characterize features present on the Earth's surface. The probabilistic line of sight is able to calculate the likelihood of attenuated visibility based on the classification and dimensions of obscurants along the path between observer and target.

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## Preface

This study was conducted for the U.S. Army Corps of Engineers. Funding was provided by the U.S. Army Engineering Research and Development Center (ERDC) Geospatial Research and Engineering (GRE) program under Project AT42, “Exploiting Sensing for Patterns—Environmental Awareness for Sensor and Emitter Employment (ESP EASEE).” The technical monitor was Dr. Keith Wilson.

The work was performed by Michael Ekegren and Kenneth Yamamoto (Signature Physics Branch, Dr. Joyce Mechling, Chief), ERDC Cold Regions Research and Engineering Laboratory (CRREL). At the time of publication, Dr. Loren Wehmeyer was Acting Chief of the Research and Engineering Division. Dr. Dale R. Hill was the Acting Technical Director for Geospatial Research and Engineering. The Deputy Director of ERDC-CRREL was Dr. Lance Hansen, and the Director was Dr. Robert Davis.

LTC John Tucker was Acting Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

## Acronyms and Abbreviations

AI-TECD	Actionable Intelligence Technology Enabled Capability Demonstration
CRREL	Cold Regions Research and Engineering Laboratory
DEM	Digital Elevation Models
DLM	Digital Model of the Last Lidar Return
DTM	Digital Terrain Models
DSM	Digital Surface Models
EASEE	Environmental Awareness for Sensor and Emitter Employment
ESP	Exploiting Sensing for Patterns
ERDC	U.S. Army Engineer Research and Development Center
GRE	Geospatial Research and Engineering
GRL	Geospatial Research Laboratory
LVIS	Land, Vegetation, and Ice Sensor
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
RGB	Red, Green, and Blue



# 1 Introduction

The U.S. Army Engineer Research and Development Center (ERDC) developed the software program Environmental Awareness for Sensor and Emitter Employment (EASEE) to model signal performance in real world conditions. EASEE incorporates the physics of terrain and weather effects on the propagation of target signatures from emission through reception. Statistical inferences are then calculated to make predictions on sensor performance. EASEE was originally based on acoustic and seismic calculations but has expanded to include several additional modalities (i.e., radio frequency and infrared). These expanded capabilities have led to a broader potential user base, some of whom have interest in more realistic predictions of visibility. More information on EASEE is available in Wilson et al. (2009).

The basic premise of a line-of-sight tool is to evaluate whether or not an unobstructed line exists between two points. This is done by using a single elevation model to represent the surface of the earth. The process is quite simple: evaluate if the direct ray, hereby referred to as a *sight line*, from observer to target falls under the height of the elevation model at any point. If it does not, then the line of sight is present; if it does, then there is no line of sight. A *viewshed* is the aggregation of lines of sight that feature one static location and many other points, generally the cells in a raster grid. For this report, the term *line of sight* refers to viewshed as well.

There are several problems with using basic line-of-sight tools for analysis at a small areal extent. The key issue is that using a single elevation model removes the intricacy of the near-surface features. The most common digital elevation models (DEM) are digital terrain models (DTM), which represents the soil or ground level, and digital surface models (DSM), which represents the tops of all features. The computer does not care what material underlies the height within a cell; it considers only the individual value for height. The two elevation models can be thought of as sheets of tinfoil on top of each other: one has more irregularities but is otherwise the same to the computer. Whichever model is used is the only one considered. The result is that all surface features, such as buildings and trees, are effectively either fully transparent or fully opaque. There are also logical issues that arise. If a DSM is used in the forest, then the calculation is based on

the highest point within a cell; this is placing the observer or the target on top of the tree (Figure 1). If a DTM is used for the same cell in the forest, there is essentially no forest as the vegetation is not present in the data (Figure 2).

Figure 1. The line of sight using a DSM. The observer, marked with a *red X*, is placed on top of a short building. Green indicates the cells with unobstructed sight lines, which include bare ground, tree tops, and the roofs of adjacent buildings.

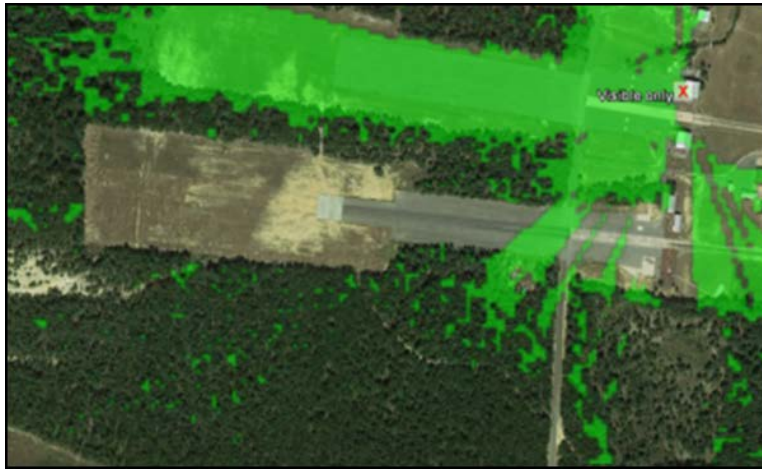
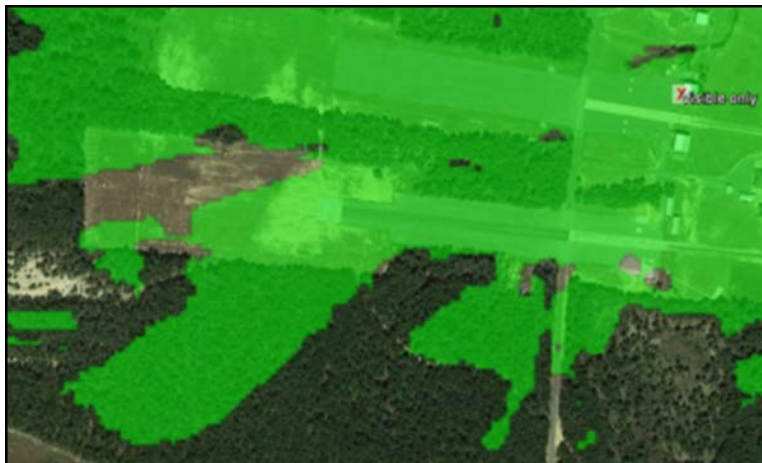


Figure 2. The line of sight using a DTM. The observer, marked with a *red X*, is in the same location horizontally but is now at ground level because the building is not incorporated in the dataset. The buildings and trees have all been removed, so only topography is considered.

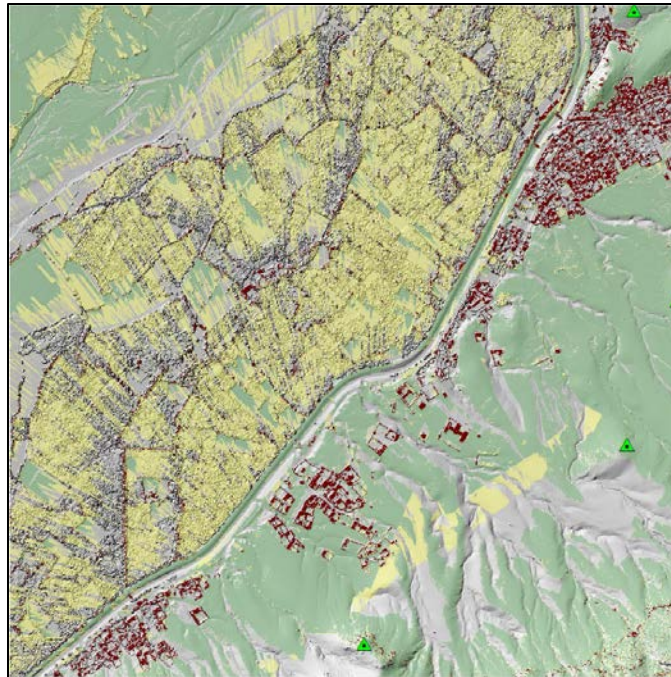


To highlight these issues, consider planning an observation position with the observer on a barren mountainside watching a valley orchard. Both models will have the observer in the same location horizontally and vertically. Each will identify the cells to which the observer has unobstructed

visibility. The cells in each analysis will have the same horizontal position, but many will be vertically different. Both elevation models will overestimate the visibility into the orchard area; the DTM will essentially remove the trees and show optimistic coverage of an open field whereas the DSM will show an unobstructed view to the treetops. While each may have a certain value to the planner, neither reflects what the end user will see from the observation position.

Figure 3 shows a valley orchard and the discrepancies that occur when comparing two viewsheds based on different elevation models. Green areas show unimpeded visibility that match in both viewsheds. Yellow areas show where terrain alone should allow visibility but where surface features are inhibiting it. Without purpose-built tools, the planner has no insight into the yellow areas, which are likely the areas of interest.

Figure 3. An orchard with four observation positions (*green triangles*) processed in ArcMap 10.0. Buildings are red and treated as impermeable barriers to visibility.



Incorporating a probabilistic line of sight allows for increased realism in modeling visibility and may aid in modeling propagation of other short wave electromagnetic signals that are affected by foliage, such as near infrared and Ku band radar. While longer-wave electromagnetic energy can be affected by vegetation, it is far less susceptible to small-feature obscuration.

## 2 Previous Work in the Field

The development of line-of-sight tools to incorporate vegetation has been an ongoing task with potential applications in various fields, such as forestry management, urban planning, and even landscaping. An early probabilistic tool addressed forest visibility through a linear distance decay using triangulated irregular networks (Dean 1997). This method calculated the total distance travelled through the canopy and sub-canopy then divided by the assumed visible extinction distance for each. While the Dean (1997) study recognized the need for separate canopy and sub-canopy decay rates, it had two significant drawbacks: it treated the decay as a linear function, and it never referenced how the required data would be obtained.

A Danish study introduced exponential decay and incorporated distinct land cover types for vegetation, each of which had a decay rate per 25 m (Peterson and Snizek 2007). This study used a digital terrain model to represent the ground level but did not include the height of vegetation; it considered only the cells with sight lines based on terrain as being vegetated.

Llobera (2007) introduced the Beer-Lambert Attenuation Law as a method for calculating exponential decay in visibility through vegetation. This study looked at the attenuation through a randomly distributed digital forest that was built on top of an elevation model. When the sight line intercepted an individual tree, it was partially attenuated. All trees had the same physical dimensions and were treated as a homogenous cross section, which led to the same attenuation by each tree.

The Beer-Lambert Law:

$$P = P_0 e^{-\alpha x}$$

$P$  = the probability of transmittance at the end of the evaluated step

$P_0$  = the probability of transmittance at the beginning of the step

$\alpha$  = the attenuation rate per unit of distance

$x$  = the distance travelled during the step

To represent the change between leaf-on and leaf-off conditions, an urban study introduced the seasonal phenology of deciduous vegetation (Bartie et al. 2010). This variability was characterized as strictly a summer or winter value with no transition between. The study modeled actual urban trees as raster datasets with canopy height, canopy base height, and terrain values. The use of raster data that reflected the true size and position of individual trees added realism that previous studies had lacked.

A study of laser penetration in forest vegetation found that the penetration of a broadleaf canopy, using different incident angles from an elevated position, remained a function of the distance travelled through the vegetation rather than the angle (Chevalier et al. 2007). While the distance through the vegetation was a trigonometric function of the incidence angle, the angle itself did not have an impact. The study subdivided the forest into three regions—the crown, ground vicinity, and lower tree line—and analyzed the permeability of the three separate regions. While this study, like others, had identified canopy and sub-canopy, it also introduced the presence of understory vegetation.

Each of the studies listed recognized the need for better tools to model visibility and attempted to add realism to the depiction of the environment. However, none was able to use pure remotely sensed data to represent dynamic and static surface features in a manner that Department of Defense users need for operating in unfamiliar regions.

### 3 Objectives and Datasets

The first step of our project was defining the logical output desired: the probability of visibility between an observer and a target that were both relative to the ground level. The probabilistic line-of-sight calculation in EASEE needed to evaluate the DTM to support the detection of ground-based targets. Because of this, the way EASEE treated the sight line between the origin and termination had to be changed so that, rather than breaking when any object was intersected, the probabilistic line of sight would attenuate the probability of transmittance along the entire path. This required EASEE to treat visibility as a float value between 1 and 0 as opposed to the traditional Boolean true or false.

The probabilistic line of sight had to identify when to attenuate the sight line. The mechanism for this identification was to simply evaluate the height of the sight line at an incremented series of points and compare it to both the DSM and DTM at the same location. In addition to determining when to attenuate, the program had to be able to identify the appropriate attenuation to apply; this required considering land cover type along the sight line. At each point of evaluation along the sight line, if the vertical position was between the DTM and the DSM, the land cover classification would also be identified. This allowed distinct attenuation rates to be applied for each of the land cover types.

The expeditionary nature of military operations meant that predictive modeling had to be able to function rapidly and with little preparation time. Datasets needed both to have a high enough spatial resolution to meet the needs of representing the complex surface features and to be realistically available for the user in the near future. The tool used only sources of remote sensing data that were available to potential users at the time of implementation.

In creating the tool, we used elevation data from the Army Geospatial Center's Buckeye lidar program. The Army Geospatial Center pre-processed the Buckeye data and distributed them as 1 m<sup>2</sup> resolution raster GeoTiff files, which included DTM, DSM, and a DLM (digital model of the last lidar return). The elevation data used could have been processed from most aerial lidar point-clouds. Using Buckeye data supported the devel-

opment of this project well because, during the lidar collection, it took high-resolution RGB (red, green, and blue) imagery, which was easier to visually interpret than the elevation models.

We selected the GeoCover land cover dataset to define what the sight line was travelling through and, therefore, to select the proper attenuation rate. GeoCover is a 30 m<sup>2</sup> resolution derived from Landsat multispectral satellite imagery. GeoCover's near worldwide data availability made it preferable to other options with limited coverage extent, such as the National Land Cover Database.

Midway through the project, the Army Corps of Engineer's Geospatial Research Laboratory (GRL) provided a higher-resolution land cover dataset. Digital Globe processed for GRL a multispectral image from Digital Globe's World View 2 satellite to show land cover at a 2 m<sup>2</sup> resolution. This was accompanied by 2 m<sup>2</sup> resolution DTM and DSM elevation files also from World View 2. The high-resolution land cover was very desirable for a visibility tool; we decided to work with it also in a separate parallel process.

An additional objective was to be able to place an observer within a building or forest and allow for a small buffer of non-attenuation. This was designed to prevent the feature that the observer was inside of from obscuring the visibility outwards. The buffer concept assumed that the observer had the ability to use an advantageous line of sight in the immediate vicinity, such as a window or foliage gap.

## 4 Incorporation into EASEE

EASEE already featured a traditional line-of-sight tool coded in Java that evaluated sight lines to gridded cells. The methods used for the probabilistic line-of-sight implementation primarily adapted the existing functions to accept additional datasets and to conduct attenuation calculations.

The first priority of the probabilistic line-of-sight tool was to get EASEE to accept multiple elevation datasets in a single calculation. EASEE was designed to operate with a single raster elevation model internally referred to as the DEM. Adding elevation models was first done by replicating the DEM variables with DSM and DLM variables. This occurred in many separate Java files but was essentially a process of repetition as all the models were geospatial raster files. Because many other EASEE components use it, we retained the DEM variable name for the terrain elevation rather than using DTM within the probabilistic line of sight

GeoCover land cover already existed in EASEE, so there was no need to incorporate it. However, future adaptation of classification attenuation rates may require modifications. The World View 2 land cover was a more complex addition than the elevation layers but principally was a replication of GeoCover with a few additional land cover classes that had to be mapped to internal vegetation and soil type variables to support existing EASEE capabilities.

We developed two methods for the probabilistic line of sight: one to use the three Buckeye elevation models along with GeoCover data and the other to use the World View 2 elevation and land cover data. The datasets available did not have a geospatial overlap, so using components from each was not possible.

EASEE used a grid of evaluation cells for its calculations; the spatial extent of the grid and the array size were both selected by the user. The resolution of the grid was used to derive the sampling distance between the observer and the target; this distance is referred to as a hop. Because the sampling distance varies from calculation to calculation, we selected the Beer-Lambert equation as the appropriate way to handle attenuation.



To add this tool, the calculation considerations for an elevated observer, such as an aircraft or tower-mounted camera, required that we modify the hop sampling to include the vertical difference from observer to target. Previously, EASEE's line of sight used only the horizontal distance to evaluate the number of samples to take; this worked for a single elevation model. With the inclusion of the surface features via multiple elevation models, the path to horizontally close cells could travel through vegetation or structures that would not have been properly incorporated without the vertical consideration.

We added a buffer around the observer by including a statement that prevented attenuation for the final series of full hops that added up to 10 m or less in length, plus one additional hop. The additional hop was to maintain the buffer if the hop distance was greater than 10 m. We chose 10 m somewhat arbitrarily to attempt to account for the sampling grid resolution and potential geo-referencing inaccuracies in the imagery used to select the observer location.

## 5 Methods

The two complete methods for implementing the probabilistic line of sight use either the Buckeye and GeoCover data or the World View 2 data.

### 5.1 Buckeye and GeoCover method

This method uses all three of the elevation models available through Buckeye. The DSM and DTM are used to represent the surface and terrain layers. The DLM is referenced to gain additional information within the land cover. Because the GeoCover has a 30 m<sup>2</sup> resolution, it can miss small features that exist within a cell. A single tree in a village or a shed in a field may not be represented in GeoCover; they could each only be a difference between the DSM and DTM. The DLM provides some context to the permeability of the object by giving the lowest level that is reached by the lidar. A building often will have very similar values for the DSM and DLM whereas a tree usually has a much larger difference. For this project, a simple criterion of 10 cm vertical separation within the 1 m<sup>2</sup> cells is treated as the distinction between permeable and impermeable. We chose the 10 cm difference to account for the variance of the uneven rooftops within the study area.

EASEE computes signal propagation from the target to the observer. This is a function of EASEE's modeling for other signature modalities. From each calculation cell, the probability of visibility starts at 1.0. The elevation of the sight line is computed at each sampling point in sequence. First, the point is compared to the height of the DTM. If it is below the terrain level, the probability is declared as 0.0; and the calculation for that cell terminates. If the sampling point is above the DTM, it is compared to the height of the DSM. When above the DSM, the probability remains at its existing value. When below the DSM, the difference between the DSM and DLM is calculated. A difference of less than 0.1 m is considered to indicate an opaque object, and the calculation terminates. If the difference is 0.1 m or greater, the object is considered permeable. The sample point is then compared to the height of the lowest third of the difference between the DSM and the DTM. The sample point's position above or below the lowest third directs the calculation to either a canopy or sub-canopy array of attenuation rates. The local land cover value, represented as an integer, is used to select the attenuation rate from the array. The existing

probability of visibility, sampling distance, and attenuation rate are entered into the Beer-Lambert equation; and the probability is attenuated. The process repeats at each sample point from target to observer.

## 5.2 World View 2 method

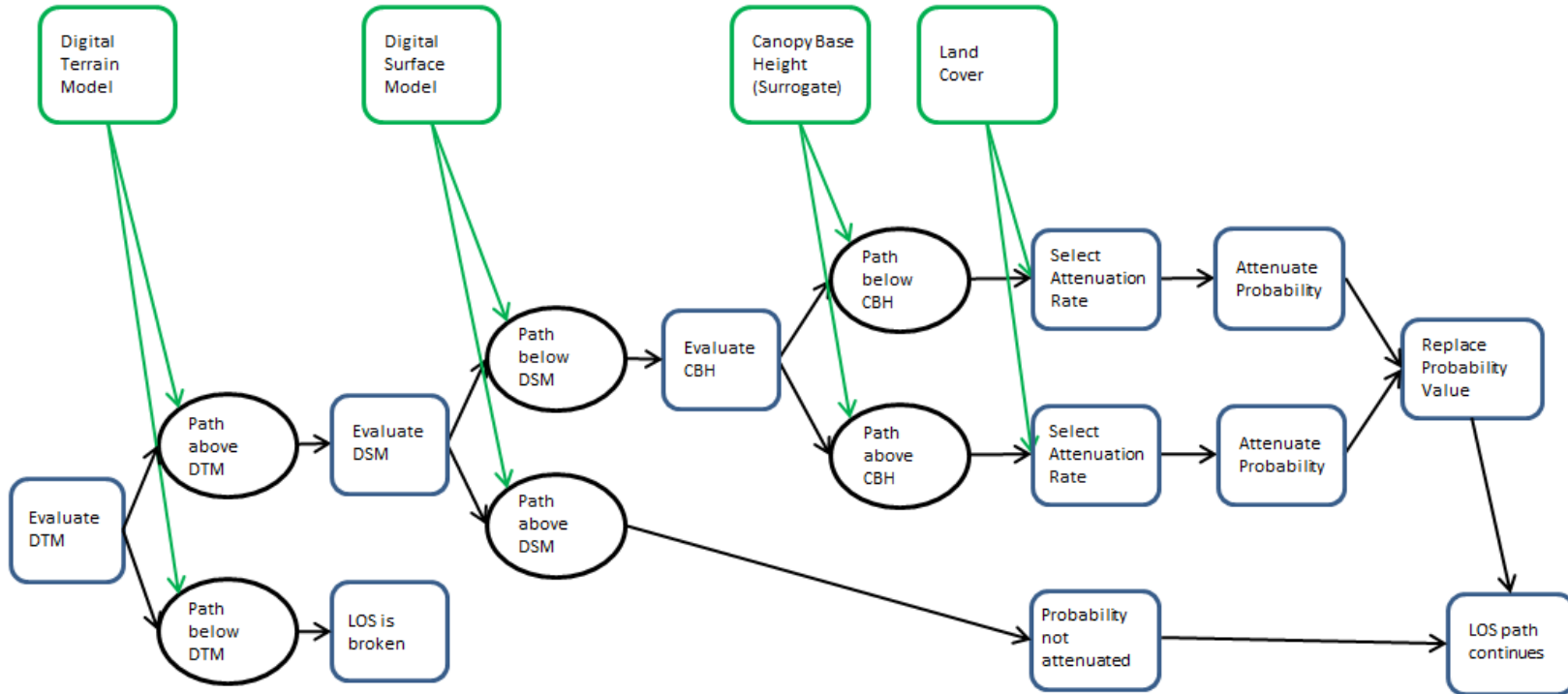
This method uses the DSM, DTM, and land cover data from World View 2. The higher spatial resolution of the land cover (2 m<sup>2</sup>) negates the need for an additional elevation dataset to give sub-cell information. Because of the resolution, the land cover of the World View 2 method is a simplified version of the Buckeye method.

From each calculation cell, the probability of visibility starts at 1.0. The elevation of the sight line is computed at each sampling point in sequence. First, the point is compared to the height of the DTM. If it is below the terrain level, the probability is declared as 0.0; and the calculation for that cell terminates. If the sampling point is above the DTM, it is compared to the height of the DSM. When above the DSM, the probability remains at its existing value. When below the DSM, the sample point is then compared to the height of the lowest third of the difference between the DSM and the DTM. The sample point being above or below the lowest third directs the calculation to either a canopy or sub-canopy array of attenuation rates. The local land cover value, represented as an integer, is used to select the attenuation rate from the array. The existing probability of visibility, sampling distance, and attenuation rate are entered into the Beer-Lambert equation; and the probability is attenuated. The process repeats at each sample point from target to observer.

Because of the computational time involved in calculating exponential decay, we introduced a shortcut into both methods to terminate calculations when the probability of visibility for a cell reaches a value of less than 0.02.

Figure 4 shows the existing workflow for the World View 2 method. Green blocks represent input geospatial data files, and blue blocks indicate calculations. This sequence is run at each sampling point along the sight line unless the terrain breaks the calculation or the probability value drops below 0.02.

Figure 4. Diagram of the evaluation process at each sample point along the sight line.



## 6 Example Output

The following set of outputs depicts the capabilities of the current implementation of the probabilistic line of sight into EASEE. The first set (Figures 6 and 7) shows a potential temporal environmental change. The second (Figures 8–10) shows a static environment but a variable sensor location.

Figure 4 shows the World View 2 land cover data used in Figures 6 and 7. In Figures 6 and 7, the observer is located at the *red X*, 20 m above the ground. The coloration shows a green to red scheme of descending probability of visibility values from 1.0 to 0.25; no coloration indicates a probability of less than 0.25. The elevation of the observer provides sight lines over the majority of the trees, but they still prevent most of the cells from being observed at the ground level. The buildings to the right have an attenuation rate of 1.0/m and block all visibility. Within the two calculations, only the attenuation rate of deciduous land cover was changed. This could represent the seasonal change between summer and winter, which produces a large difference in the visibility to the south of the sensor.

Figure 5. The World View 2 land cover data showing two small runways and their associated forest clearings. This is the land cover dataset used in the calculations for Figures 5 and 6.

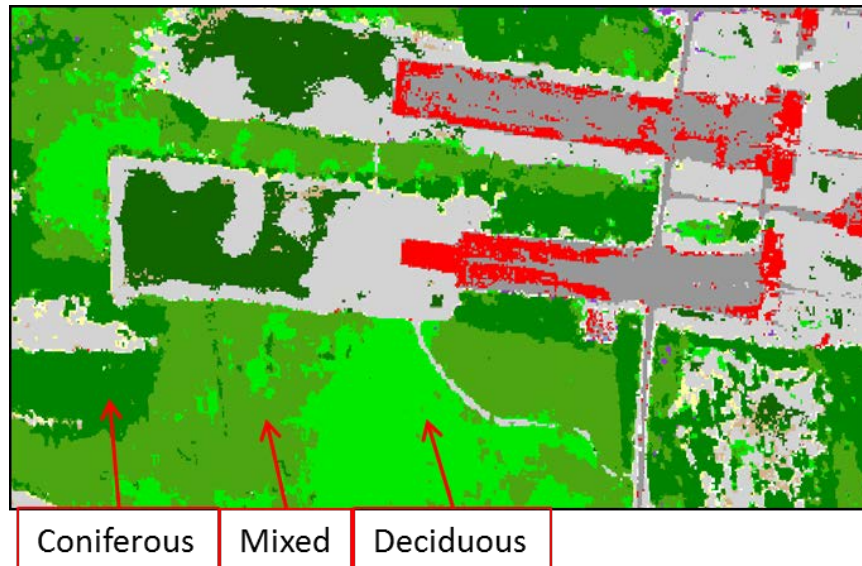


Figure 6. The probability of visibility using per meter canopy attenuation rates of 0.2/m for all land cover types.

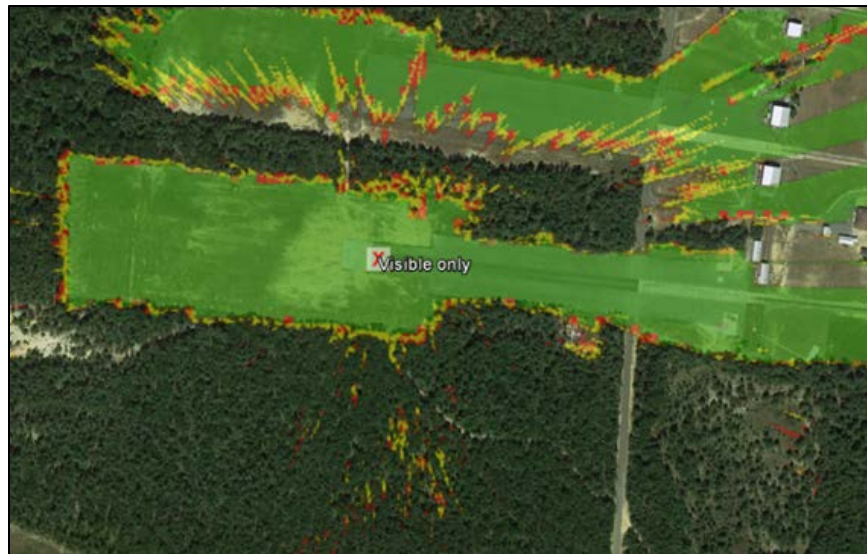
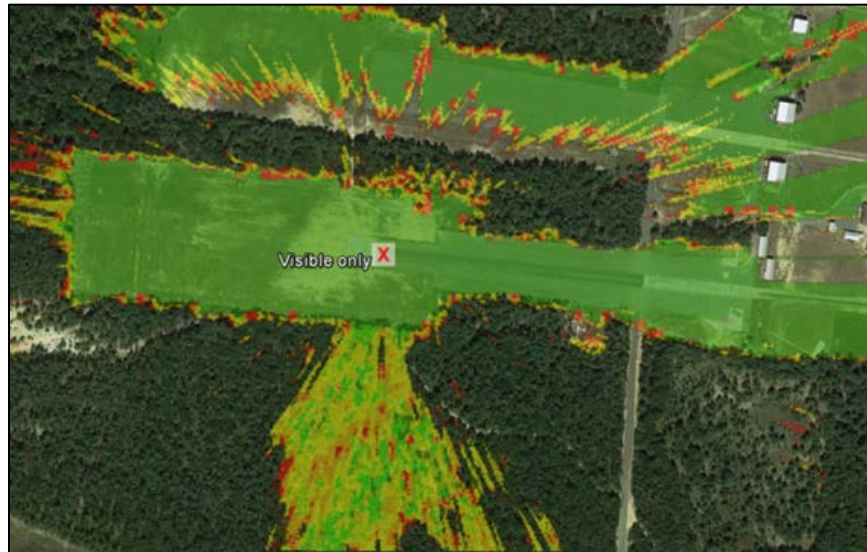


Figure 7. The probability of visibility when the deciduous rate is changed to 0.02/m.



In Figures 8–10, the probability of visibility is calculated from three different elevations at the same horizontal location: the first two are from inside of a building on the first and second floors, respectively, and the last observation is from the roof. Even with a 10 m buffer, the presence of short trees near the building causes strong visibility restrictions from the lowest level.



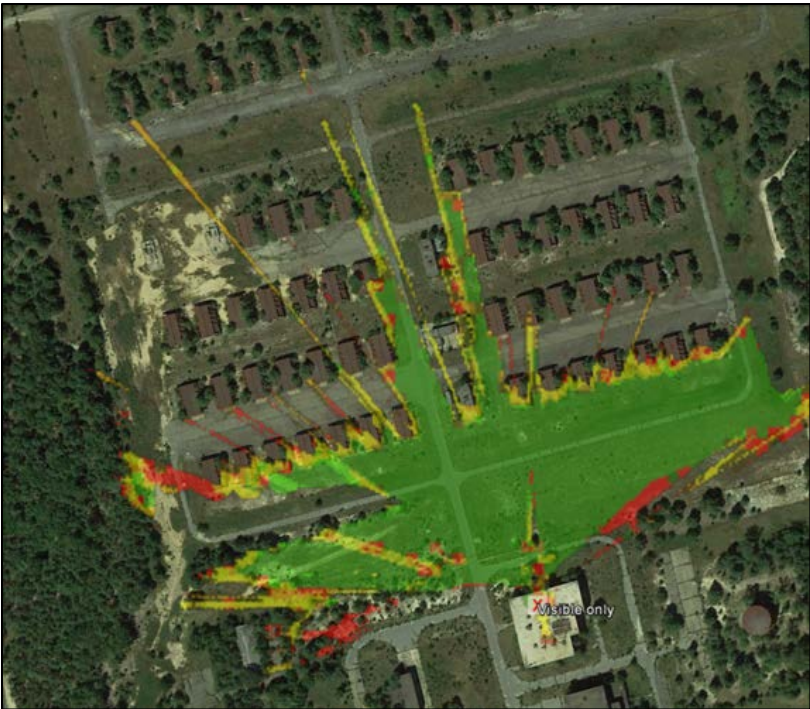
Figure 8. The probability of visibility from the first floor of a two story building.



Figure 9. The probability of visibility from the second floor of a two story building.



Figure 10. The probability of visibility from the roof of a two story building.





## 7 Continuing Work

Attenuation rates used for each land cover class were based on rough estimates rather than on any field collection. The creation of the functioning attenuation mechanism was the key task with supporting data collections intended to be conducted later. The proper attenuation rates are likely linked to biome, latitude, and seasonal variance and are likely to be the subject of follow-on research.

The seasonal phenology of vegetation needs to be represented by incorporating time series remote-sensing data. By using repeating remote sensing, the dynamic condition of vegetation within individual raster cells can be considered rather than applying a general condition to the entire calculation extent. Multi-spectral satellite imagery is the ideal collection method for this data because of its passive and worldwide availability. High-resolution satellites are additionally capable of providing data that can indicate the condition of individual or small communities of plants. The Normalized Difference Vegetation Index (NDVI) is a useful tool for monitoring the health of vegetation; and the index of the red and near infrared bands indicates the relative concentrations of chlorophyll and mesophyll, which support photosynthesis. The growth of new leaves and the dropping of leaves are key events for visibility considerations; each tends to occur over the span of a few to several weeks and can likely be identified through NDVI. Incorporating the vegetation health based on spatial characteristics will provide a more accurate depiction of the environment.

A method is needed to separate the internal structure of vegetation into canopy and sub-canopy; without it, all cells would be homogenous columns from DTM to DSM. The desired data is an elevation raster that represents the canopy base height of a forest. While this type of product does exist in the United States for wild fire management through the Landfire Program ([landfire.gov](http://landfire.gov)), it is not available worldwide and is not intended for use at the scale of interest to the EASEE user. For a temporary solution, we considered the lowest third of the difference between the DSM and DTM to be the sub-canopy. The canopy and sub-canopy attenuation rates are only different for classes that should feature trees. This is an implementation intended to be replaced as better data becomes available. Along with canopy base height, a model of understory vegetation will also add

valuable information about vegetated environments. The National Aeronautics and Space Administration's (NASA) Land, Vegetation, and Ice Sensor (LVIS) lidar shows continued work in developing capabilities to remotely collect relevant data on internal forest structure (NASA, n.d.). Adding this type of data will likely require adapting EASEE to read additional raster elevation models (as described above) and to evaluate the sight-line sampling location against the height of the new models.

Atmospheric obscurants also play a role in visibility; fog, dust, smoke, and airborne particulates are all hindrances. The effects of atmospheric obscurants are being incorporated into other portions of EASEE; there may be future modification to the probabilistic line of sight to add them, but it is not part of the existing objectives.

One of the key outputs of EASEE is geospatial probability of detection based on target signature, propagation physics, and received signal compared to background noise. The probability of visibility is not a probability of detection but can support it by improving the realism of environmental effects on propagation. We have not yet established whether the calculated probability of visibility to a location can directly be considered as the proportion of the target that is visible at that location. This would likely be the case based on the intended sampling methodology of using visible target proportions to create proper attenuation rates. Treating a target as fractionally visible rather than entirely visible or not visible would allow for future in-depth analysis of optical resolution and contrast with the background.

While still under development, a need arose to incorporate a simplified version of the probabilistic line of sight into the instance of EASEE being use in an Army experimental program. Appendix A discusses the simplified version and bypasses the issues listed above to provide a rapid solution to the issue.

## **8 Conclusions**

Within EASEE, the probabilistic line of sight aids in modeling the signal propagation of the visible spectrum with the potential to also improve other shortwave electromagnetic modalities. By incorporating multiple datasets to better characterize the physical environment, the probabilistic line of sight produces a more realistic representation of the effects that near surface obscurants have on visibility. Because it uses only remotely sensed data, the capabilities are potentially available worldwide on short notice. Though there remains significant work to refine and improve the environmental representation, the tool has successfully met the original objectives of the project.

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## Appendix A: Useage in the AI-TECD

EASEE has recently been a participating technology in an Army experimental project called the Actionable Intelligence Technology Enabled Capability Demonstration (AI-TECD). During this project, soldiers at Fort Dix, NJ, used EASEE for mission planning at a July 2014 event. The users tended to focus on the human as a sensor, so the combined effects of hearing and visibility were of concern. At the time, EASEE was only able to recognize one elevation file, which was a problem for combining the two modalities in a forested environment (Figures A1–A4).

Figure A1. The acoustic detection within EASEE, based on the propagation over a DTM.

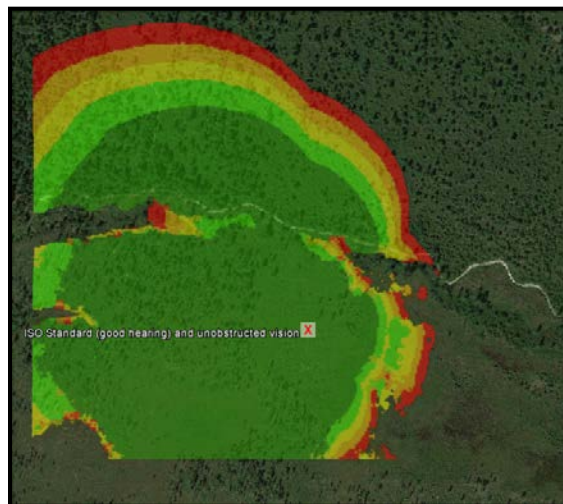


Figure A2. The visual detection within EASEE, based on the DSM.



Figure A3. The combined acoustic and visual detection using only a DTM. The absence of trees allows the visibility to be overestimated.

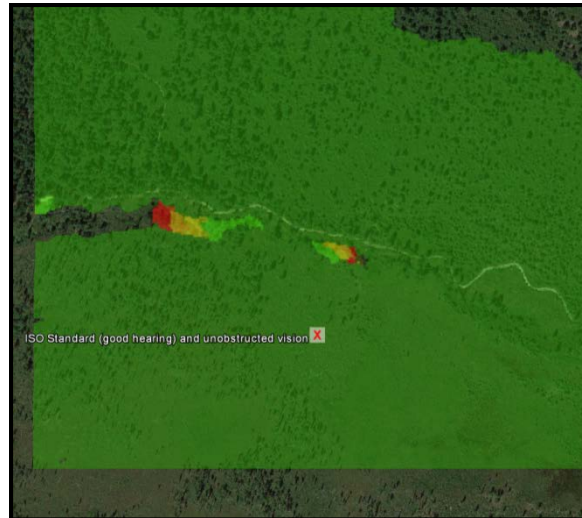
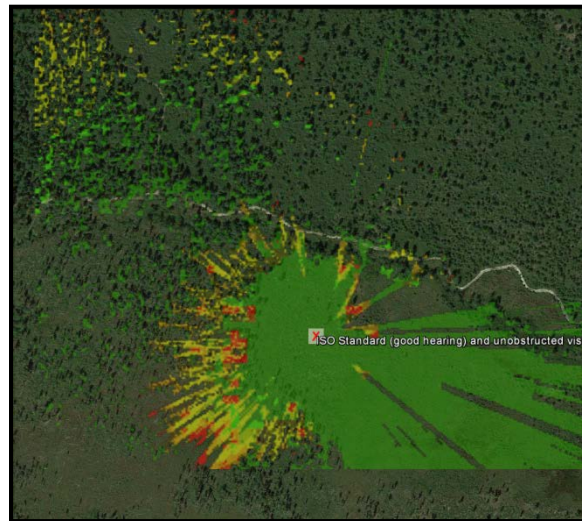


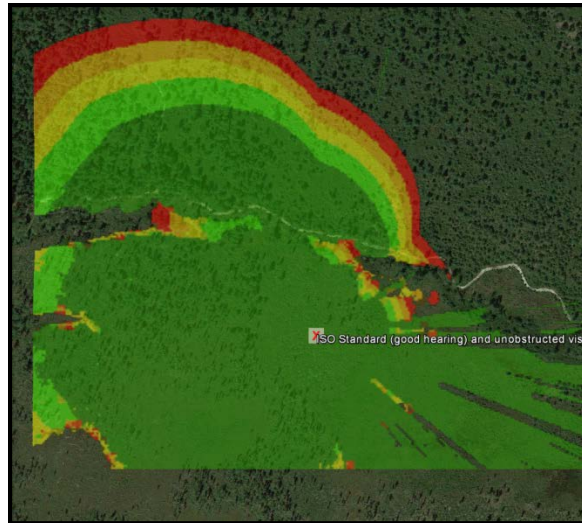
Figure A4. The combined acoustic and visual detection using only the DSM. The trees are incorporated and limit visibility, but the acoustic propagation is forced to diffract over them as if they were boulders.



To prevent results like those shown in Figures B1–B4, we instructed the soldiers participating in the July 2014 event to select individual modalities and to toggle between the DTM and DSM. This was not an ideal situation, so we adapted a version of the probabilistic line-of-sight tool to create a quick solution before the follow on event in July 2015. This version used only the two elevation models; any time the DSM was intercepted, the probability was attenuated to 0, and the sight line was broken. This meth-

od provided a rapid mechanism to reduce the workflow and to alleviate the additional burden on the user. While this did not incorporate the desired attenuation in vegetation, it did allow the modalities to better function together by incorporating the multiple elevation models. Figure B5 shows the results.

Figure B5. The combined acoustic and visual detection with the incorporation of the probabilistic line-of-sight tool.



# REPORT DOCUMENTATION PAGE

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<b>14. ABSTRACT</b> This report covers the effort to better represent the effects of natural and man-made surface features on visibility by incorporating probabilistic methods into a line-of-sight tool within the Environmental Awareness for Sensor and Emitter Employment (EASEE) software package. Traditional line-of-sight methods are strictly binary: the possibility of seeing from one point to another is either yes or no without a consideration for what is in-between. The major issue that hinders traditional line-of-sight tools is that they use only one elevation model in their calculations. A single elevation model oversimplifies the complexity of the physical environment, creating unrealistic representations of both the Earth's surface and visibility. While computationally fast, this type of tool results in output that is often conceptually flawed. The developed probabilistic line-of-sight algorithm corrects for this issue by incorporating multiple elevation models and land cover data to better represent and characterize features present on the Earth's surface. The probabilistic line of sight is able to calculate the likelihood of attenuated visibility based on the classification and dimensions of obscurants along the path between observer and target.					
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