Abstract
The US currently operates Space Situational Awareness (SSA) systems with the purpose of tracking space objects for collision avoidance and detecting adversarial threats in orbit. At great distances an image of the object cannot be observed. But a light curve can be generated based on the light emitted from the tracked object. Different light curves are produced based on the shape and material of the object and the orbit taken to observe said object. Bi-directional reflectance distribution functions (BRDF) are used to generate these light curves based on how the light is reflected by the object. However, large variances occur based on the BRDF model used. It is important to analyze how these variances effect the analysis of the target object. The object of this study is to determine how the variance in the BRDFs affects the analysis of the unknown object. The study showed that diffuse materials result in high relative variances among the BRDFs while specular materials result in low relative variances.

Background
A previous thesis from AFIT attempted to use light curves to classify unknown objects in space at great distances. Bi-directional Reflection Distribution Functions (BRDFs) are used to derive these light curves (Figure 1). However, great variances occur when using different BRDFs with different materials. The goal of the project was to examine the error between BRDFs that occur across different materials.

Methods
To begin, five materials and five BRDFs were selected to be examined. In order to compute the BRDFs parameters for each material had to be chosen. MATLAB code using a fitting program fitted each BRDF to each material given data from another source. An example of a fitted BRDF to material data is shown in Figure 2. Next, 16 orbits were simulated using the COAST software as described by the previous thesis (Figure 3). From these orbits the incident and reflected angles of the light were computed as well as the distance between the target object and inspector satellite (Figure 4). Using the calculated angles and ranges a geometric attenuation term can be computed like in Figure 5. Using this and the material parameters all five BRDFs the light curves were calculated using MATLAB for each of the five materials and each of the 16 orbits for a total of 80 different case. From the five different light curves of each case the mean light curve, standard deviation, and relative standard deviation were calculated.

Results

• Maxwell Beard Material Purple Paint Parameter Fitting Example
• Inspector Relative Position to Target
• Example Target Object With Vectors Used to Compute Angles

Conclusions
It is clearly shown that the light curves in Figure 6 and Figure 7 have the same shape of the geometric attenuation term graphed in Figure 5. From this it can concluded that the orbit of the satellite around the target object determines the shape of the light curves but does not introduce error into the data. Rather, the material of the object in question determined the magnitude of the difference between the BRDFs as some BRDFs tend to be more actuate at describing different materials than others. In general what was found was that the more diffuse materials (i.e. Black Oxidized Steel shown in Figure 7) caused the largest spread in the BRDF’s. Specular materials (i.e. Red Phenolic shown in Figure 6) caused very little variance amongst the light curves.

Looking Ahead
The work done this summer is just a small fraction of the overall picture of the project. The end goal is to be able to use light curves to identify distant objects in space. However, this project only looked at how the BRDFs produced error when used to calculate light curves of objects at great distances. Overcoming this error between BRDFs will be an interesting challenge. The next step of this project would most likely involve looking at how the different BRDFs predict object shapes and how the material effects said prediction. Also, some BRDFs (i.e. LaFortune) exhibit incorrect behavior when analyzing vertices of an object. As this project only examined cubic objects, another area of interest would be to examine how BRDFs handle the analysis of shapes with multiple sides or protruding edges (i.e. solar panels) across multiple different orbits. Only when the extent of the inaccuracies of BRDFs are understood can this project be applicable.

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