REPPERGER RESEARCH INTERN PROGRAM

RESEARCH PROJECT #: AFRL-RHD-26-05

Physics-Based Bidirectional Reflectance Distribution Function (BRDF) Modeling for High-Fidelity Simulation of Degraded Visual Environments (DVEs)

PROJECT DESCRIPTION: Operators frequently encounter DVEs where perception and safety are critically compromised. A primary cause of DVE is the complex interaction of light with various surfaces, especially under low-angle illumination from sources like the sun, which creates intense glare, backscatter, and deep, misleading shadows. Accurately simulating these real-world visual challenges is essential for developing effective training systems and robust analysis capabilities. To achieve this high-fidelity simulation, a sophisticated understanding of surface reflectance is required. This project focuses on the BRDF, a fundamental model that describes how light scatters from a material. While standard rendering engines use generalized BRDFs, they often fail to capture the nuanced visual effects of specific real-world materials. This research moves beyond generic models by conducting a deep analysis of advanced BRDF equations (e.g., the Hapke model) to directly link their parameters to the measurable physical properties of a given surface, such as particle size, texture, and composition.

As a demanding and high-impact application of this methodology, this project will address the extreme visual environment of the lunar south pole. The conditions there, characterized by perpetual low-angle sunlight and a unique regolith surface, present a formidable DVE and serve as a perfect test case for validating our advanced BRDF model. This work has direct applications for NASA-partnerships, supporting the development of crucial VR training tools for astronauts who will face these perceptual challenges. The ultimate goal is to develop a validated, physics-based framework for generating high-fidelity surface models for any DVE. While immediately applicable to NASA's critical training needs, the foundational capability developed will be broadly relevant to our RHDs core mission. The resulting insights and techniques can be adapted to model terrestrial scenarios involving glare and low-angle scatter from surfaces like sand, snow, or wet asphalt, directly enhancing our simulation and analysis capabilities for a wide range of operational environments.

LEARNING OBJECTIVES: The participant will gain a fundamental understanding of light scattering physics and advanced radiative transfer models, such as the Hapke BRDF. They will develop practical skills in conducting interdisciplinary literature reviews, translating physical material properties into computational parameters, and validating the output of high-fidelity virtual reality simulations.

ACADEMIC LEVEL: Undergraduate**;** Masters

DISCIPLINES NEEDED: Physics (Computational), Engineering (Aerospace), Astronomy/Astrophysics

RESEARCH LOCATION: JBSA Fort Sam Houston, Texas

The material was CLEARED on 10 Dec 2025; Reference Number: AFRL-2025-5591.

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RESEARCH MENTOR: Clint Lanham
Master's of Science in Physics, Virginia Tech, 2023

Clint Lanham is a research physicist in the Air Force Research Laboratory's Optical Radiation Branch (711 HPW/RHDO). In his current role, he works on the Bioeffects Division's modeling and simulation team, applying his computation and theory background as a subject matter expert, scoping new research initiatives and leading technical discussions to develop physics-based projects and implement component library integration towards directed energy risk assessments. Prior to his work with the Air Force, Clint was a Health Physicist at UCLA, where he managed comprehensive radiation safety programs for university facilities. His research background is rooted in nuclear, particle, and condensed matter physics, with a focus on data analysis, physics-based modeling, and Monte Carlo simulations. His current research pursuit areas include modeling high-energy laser-particle interactions, condensed matter theory for advanced protective equipment, reflectance modeling for vision effects, and digital engineering.

Photo courtesy of Air Force Research Laboratory