Digital Pathfinder for Synthetic Morphogenesis and Opto-Geometric Reprogramming

PROJECT DESCRIPTION: Traditional mechanobiology and bioeffects modeling rely on patchwork Euclidean finite element analysis. These traditional models treat laser interactions primarily as thermal damage or linear ablation, failing to capture the complex nonlinear 3D deformations (e.g., buckling, warping, and puckering) that occur during active remodeling. This research project introduces Geometric Mechanobiology via a Non-Euclidean Elastic Framework (NEEF). By treating cellular structures as physical realizations of metric tensors, NEEF models 3D morphogenetic shape changes as the physical minimization of internal geometric frustration.

This project seeks to develop a computational prototype to model localized laser-induced metric shrinkage. Using a literature baseline for validation, the team will implement energy minimization routines to simulate the out-of-plane buckling transition. This project moves away from high-cost hardware setups and focuses on building a high-value intellectual asset: a stable computational pipeline that demonstrates how light can be used as a "synthetic morphogen" to program complex 3D shapes. The resulting codebase will inform next-generation Air Force assessment tools and lay the foundation for 4D materials and active-manifold soft robotics.

LEARNING OBJECTIVES: Under the guidance of a mentor, you will gain hands-on experience to complement your education and support your academic and professional goals. Along the way, you will engage in activities and research in several areas, including but not limited to:

1. Gain a foundational understanding of differential geometry applied to continuum mechanics, nonlinear elasticity theory, and variational energy functional minimization.
2. Develop hands-on, advanced computational skills by scripting finite element models and running simulation pipelines on high-performance computing platforms.
3. Learn to translate biochemical signaling into macroscopic tensor parameters.
4. Perform cross-code validation against established biophysical literature.
5. Present research findings to a multidisciplinary Air Force research team.

ACADEMIC LEVEL: Master's, Doctoral
DISCIPLINES NEEDED: Engineering (Bio), Physics (Computational), Any
RESEARCH LOCATION: JBSA Fort Sam Houston, Texas
RESEARCH MENTOR: Clint Lanham
Master's of Science in Physics, Virginia Tech, 2023

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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 areas include modeling high-energy laser-particle interactions, condensed matter theory for advanced protective equipment, reflectance modeling for vision effects, and digital engineering.

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