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Uncertainty-enabled Design of Electromagnetic Reflectors with Integrated Shape Control

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Electromagnetic reflectors, such as mirrors, composed of thin films and smart materials can provide lightweight, compactly-stowed, controllable alternatives to traditional heavy, ridged reflectors deployed in space structures. The shape of an electromagnetic reflector is critical to its performance. For example, the clarity of images acquired by optical telescopes depends highly on the accuracy of their mirrors' shapes, such as paraboloids. In traditional systems, the reflector shape is set during fabrication; however, assembly imperfections and environmental conditions can lead to an inadequate shape once operational. An infamous example is the Hubble Space Telescope, which ultimately required costly modifications in orbit to address its shape errors. Active shape control can alleviate issues with shape errors, though its effectiveness is limited by inherent uncertainty and variability in design, material, and environment parameters and conditions. This project investigates a flexible laminate that can be the foundation of a reflector that is shape controlled by a piezoelectric film actuated by distributed voltages. Design guidelines and tolerance specifications are sought to enable a reflector with low shape error despite the presence of variability and uncertainties. The project aims to develop a computationally efficient model that estimates reflector shape given an array of control voltages and subsequently determines performance sensitivities and probabilistic deformations. This model-based analysis is intended to provide supporting information that addresses design feasibility and that facilitates further evaluation using higher-order modeling and experimental techniques.

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