# “Multi-Objective Optimization of Spacecraft Trajectories for Small-Body Coverage Missions”

**David Hinckley, PhD student University of Vermont**

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## Background & Significance

When conducting a small-body mission there is often the need to develop a detailed map of the surface. Topography-based position tracking and landing operations have direct need of detailed information regarding the body’s surface. To acquire such information survey trajectories must be flown in which images of the surface are taken which must adhere to a standard of coverage in order to learn all of the necessary facets of the surface. During survey trajectories, a camera on-board the spacecraft must take the proper sequence of images, focusing on the surface at specific locations at specific times. Finding the trajectories and associated image target sequences is a difficult multi-objective optimization task with many competing objectives such as achievable coverage, spacecraft effort, and the time required to achieve said coverage. This work focuses on the trajectory optimization portion of this task separates the tasks into a trajectory optimization of bulk quantities and a image targeting optimization given a trajectory.

## Project Goals

The goal of this work was to develop a means of optimizing trajectories about small celestial bodies with non-spherical mass distributions and the associated image targeting sequences for coverage missions. This optimization would attempt to maximize coverage quantities (coverage defined using an official NASA definition), minimize the time required to achieve a portion (90%) of that coverage, and, in the case of image sequences, minimize the rotational effort exerted by the spacecraft. Solutions to both problems are evolved and evaluated separately, each within an adapted Non-dominated Sorting Genetic Algorithm 2 (NSGA2) framework; the adaptation being a replacement of the natural Genetic Algorithm (GA) operations with those used in Differential Evolution (DE) for the trajectory problem. Various problem specific factors are considered in the selection and adaptation of the mutation and recombination operators for the NSGA2 implementations.

## Summary of Key Findings

Since the optimization considers multiple objectives, a collection of solutions is returned as opposed to a single imaging schedule. This collection represents a non-dominated front which is a set in which no solution is better than any other solution in every objective. The front captures the trade-space between different objectives. The solutions for this problem are the initial velocities for trajectories about the small-body in question. Below is a sample coverage result returned from an optimization run of an image sequence that used a found optimal trajectory. The colored facets show the number, out of 5, of the coverage conditions that were satisfied: A black cell means no requirements were met; a red cell means 1 requirement was met; a yellow cell means 2 requirements were met; a purple cell means 3 requirements were met; a blue cell means 4 requirements were met; and a green cell means all requirements were met.