MULTI-OBJECTIVE OPTIMIZATION OF SPACECRAFT TRAJECTORIES FOR SMALL-BODY COVERAGE MISSIONS

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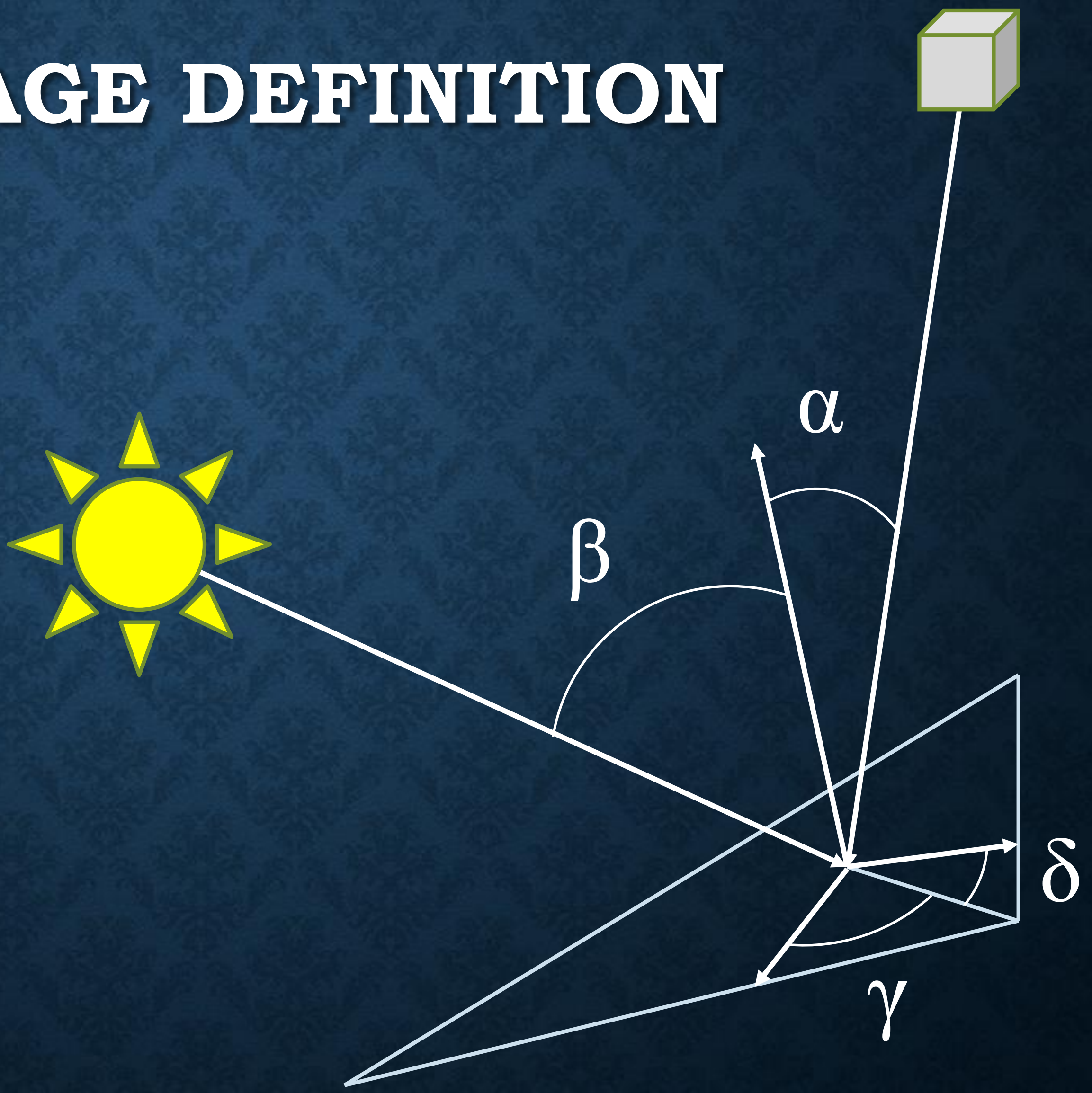
INTRODUCTION

- Small-body landing and topographical navigation operations require surface information
- Topographical maps require images to be taken that meet a standard of “coverage”
- For a given trajectory, the targeting sequence of images is a nontrivial optimization problem

COVERAGE DEFINITION

- Emission angle: α
- Incidence angle: β
- Spacecraft azimuth angle: γ
- Solar azimuth angle: δ



COVERAGE IMPLEMENTATION

ea_1	…	ea_n	ia_1	…	ia_m	sca_1	…	sca_q
1	…	n	n+1	…	m+n	m+n+1	…	m+n+q
2^1	…	2^n	2^{n+1}	…	2^{m+n}	2^{m+n+1}	…	2^{m+n+q}

Super-Increasing List

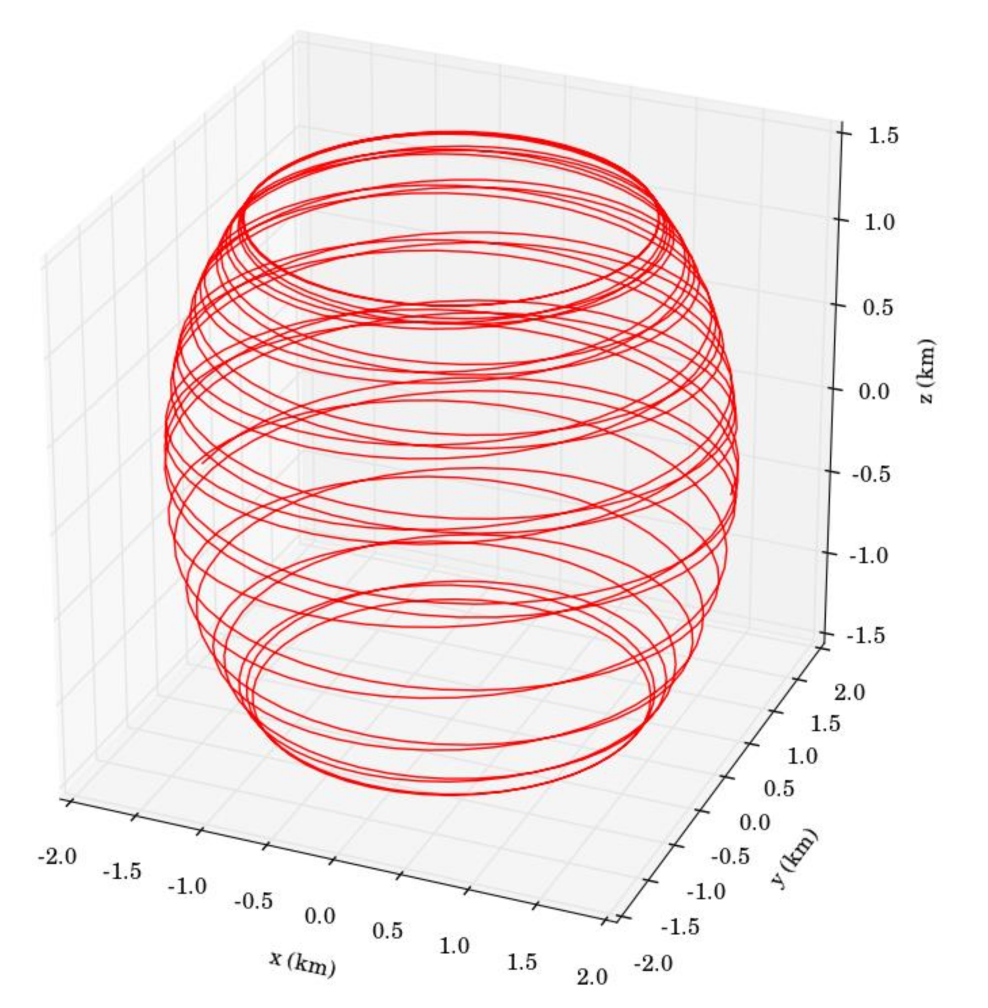
NON-DOMINATED SORTING GENETIC ALGORITHM-2

- K. Deb, A. Pratap, S. Agarwal and T. Meyarivan, "A fast and elitist multiobjective genetic algorithm: NSGA-II," in IEEE Transactions on Evolutionary Computation, vol. 6, no. 2, pp. 182-197, Apr 2002. doi: 10.1109/4235.996017
- Multi-Objective Evolutionary Algorithm (MOEA)
- Non-Domination and the Non-Dominated Front

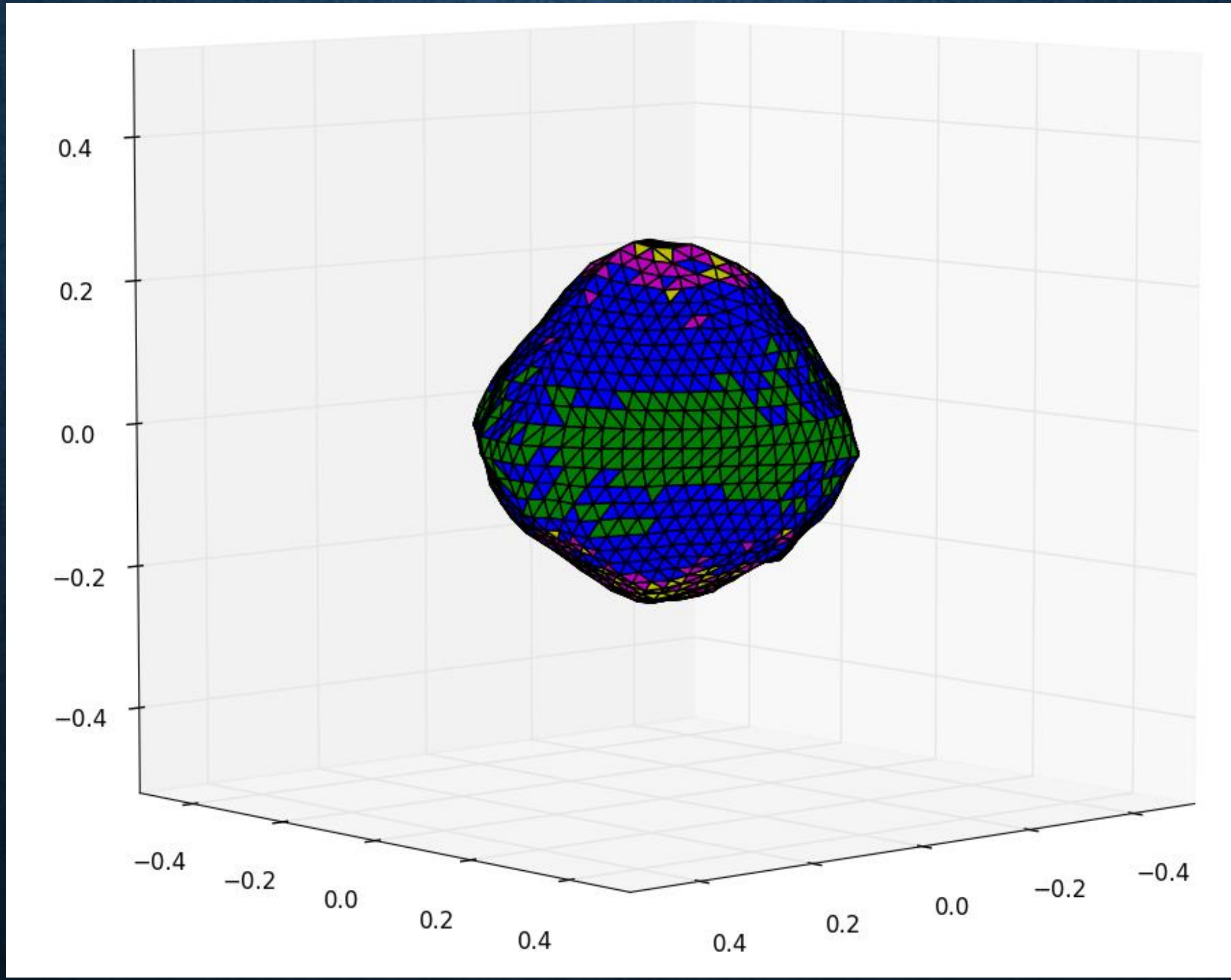
TEST PROBLEM

- Body of interest: Bennu
- 45° inclined trajectory initialized at 2 km from center of mass in the equatorial plane
- "Circular" initial velocity
- Timespan of 5 days with image opportunities every 5 minutes
- Objectives:
    - Maximize coverage
    - Minimize required change in rotation rate

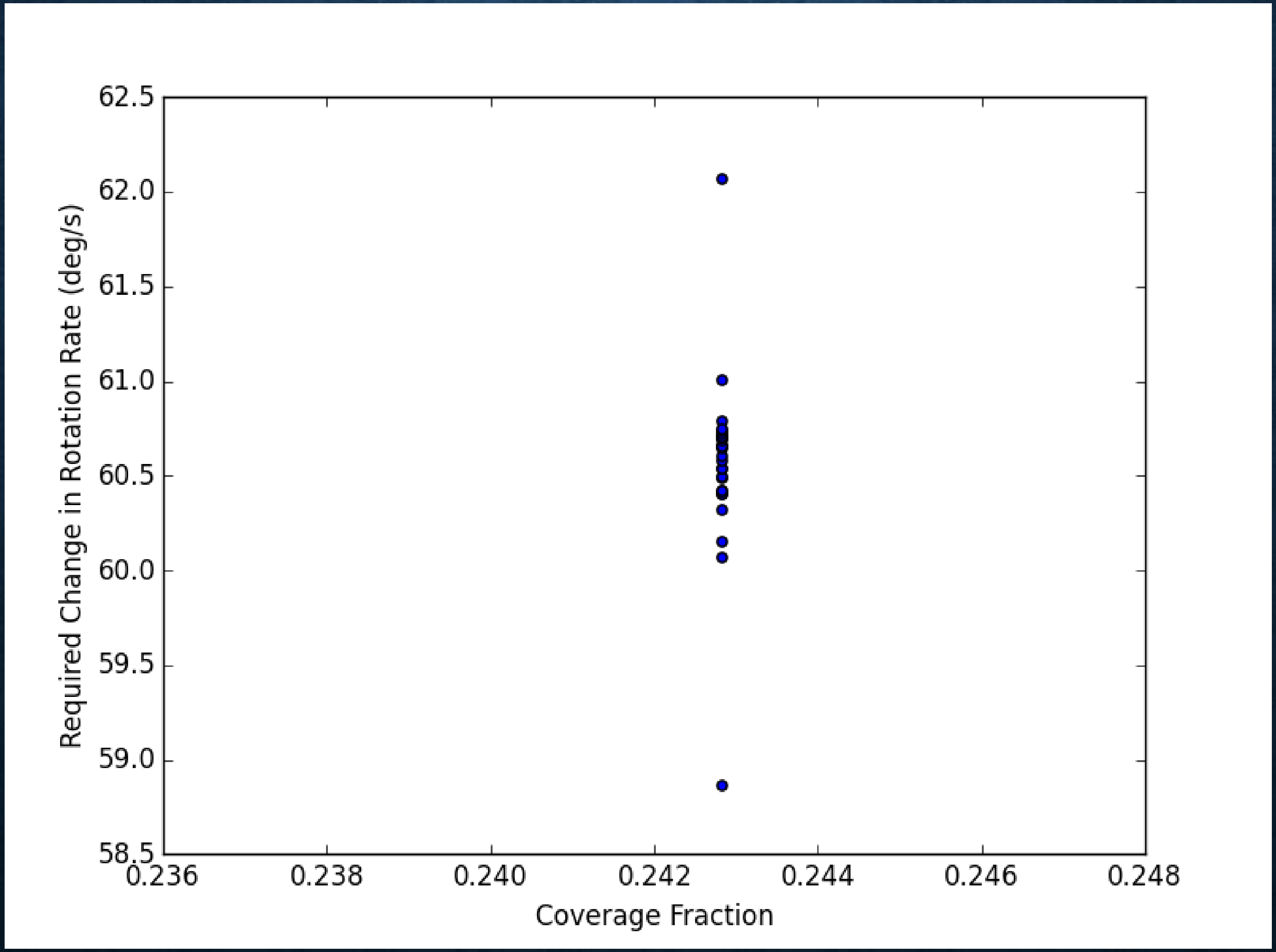
TEST TRAJECTORY



MAXIMUM ACHIEVABLE COVERAGE



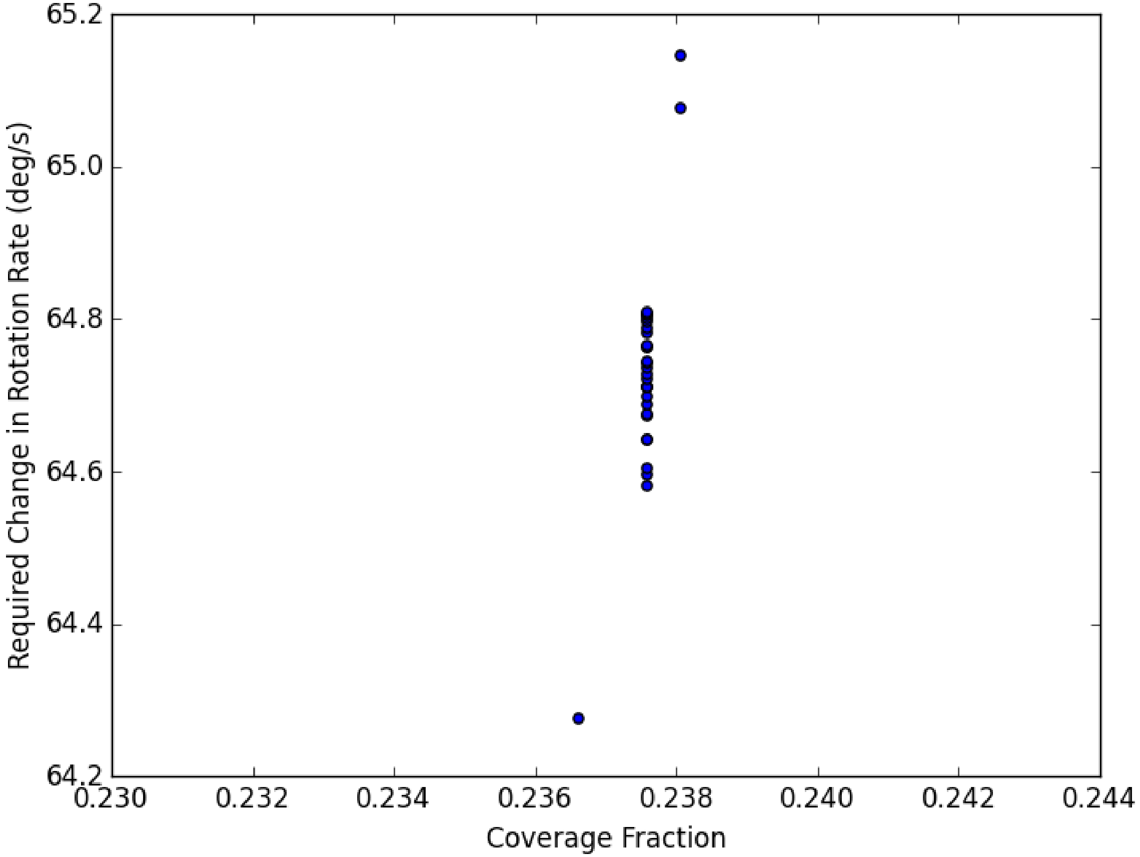
RESULTS



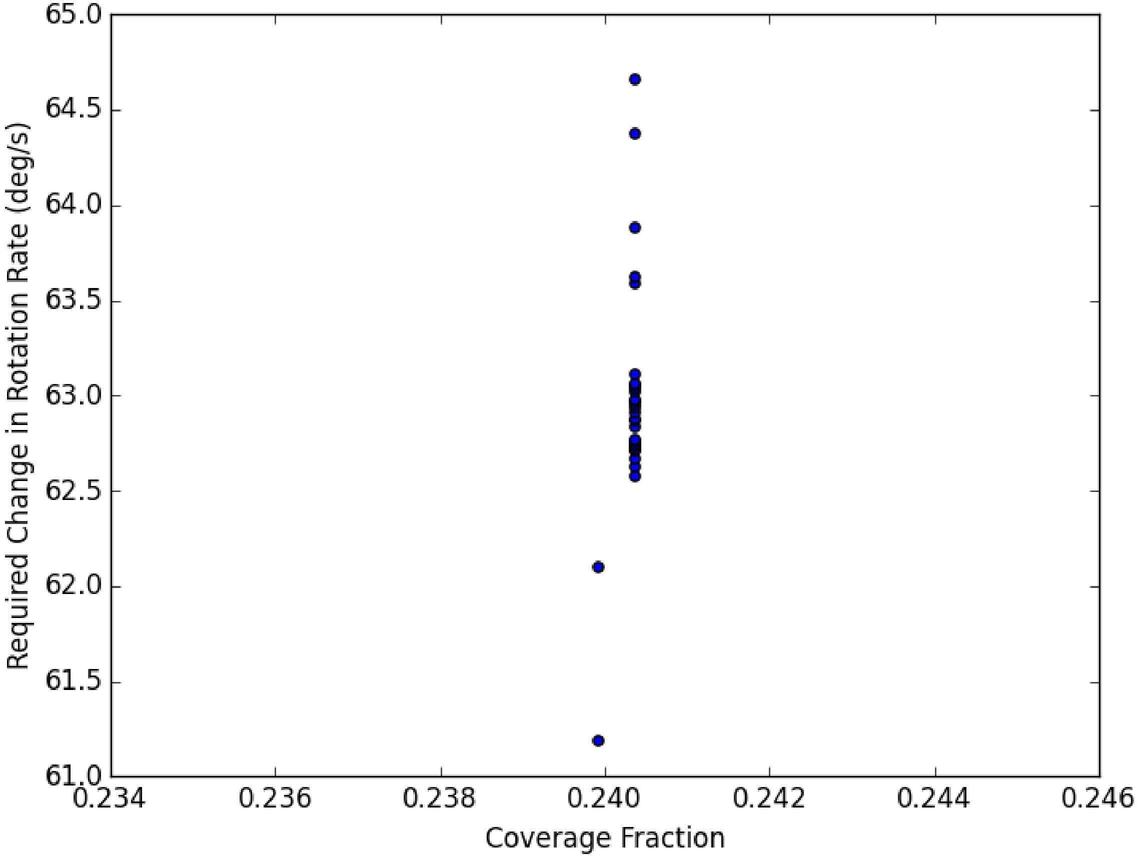
1750 generation

RESULTS

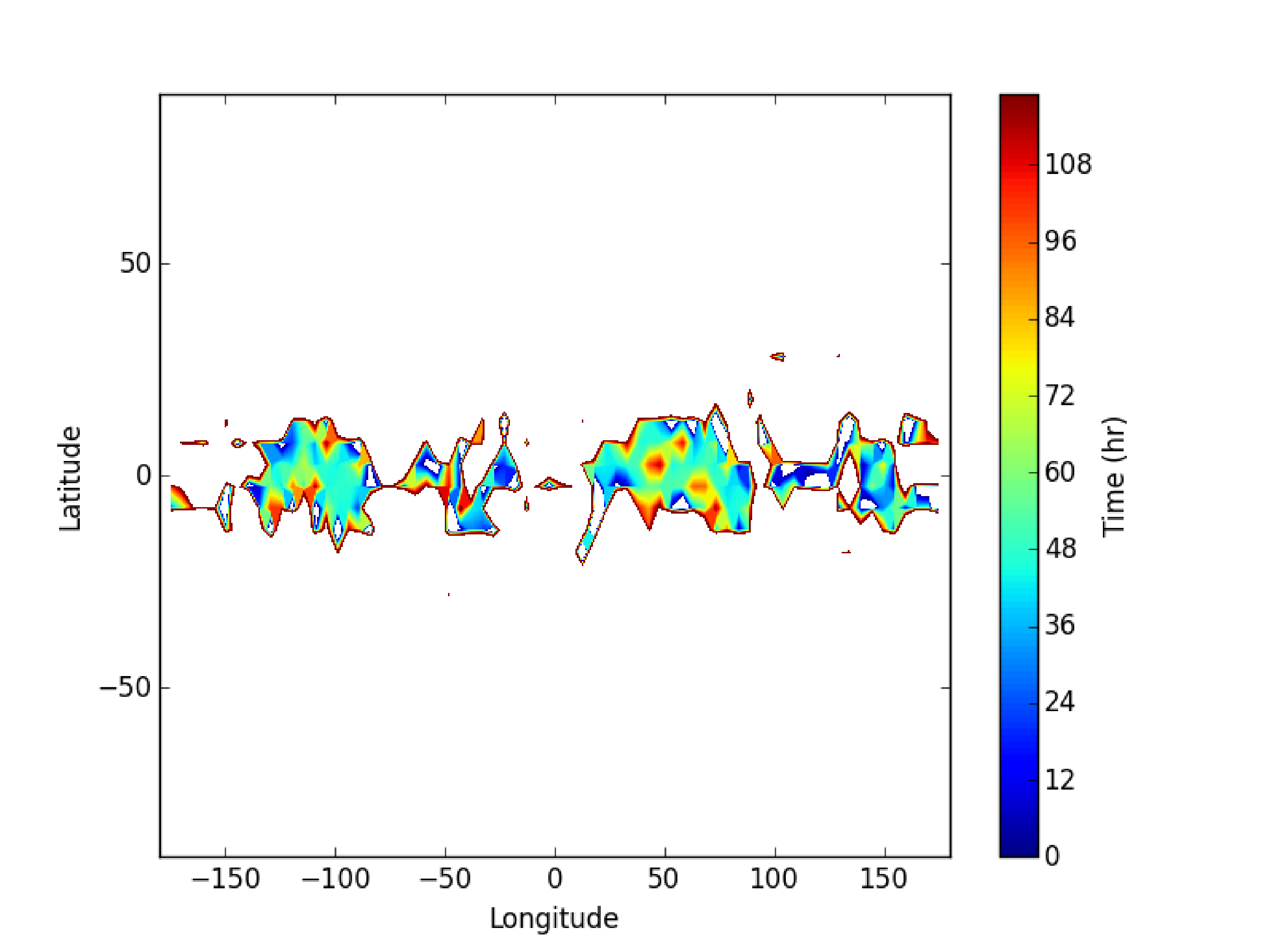
500 generation



1000 generation

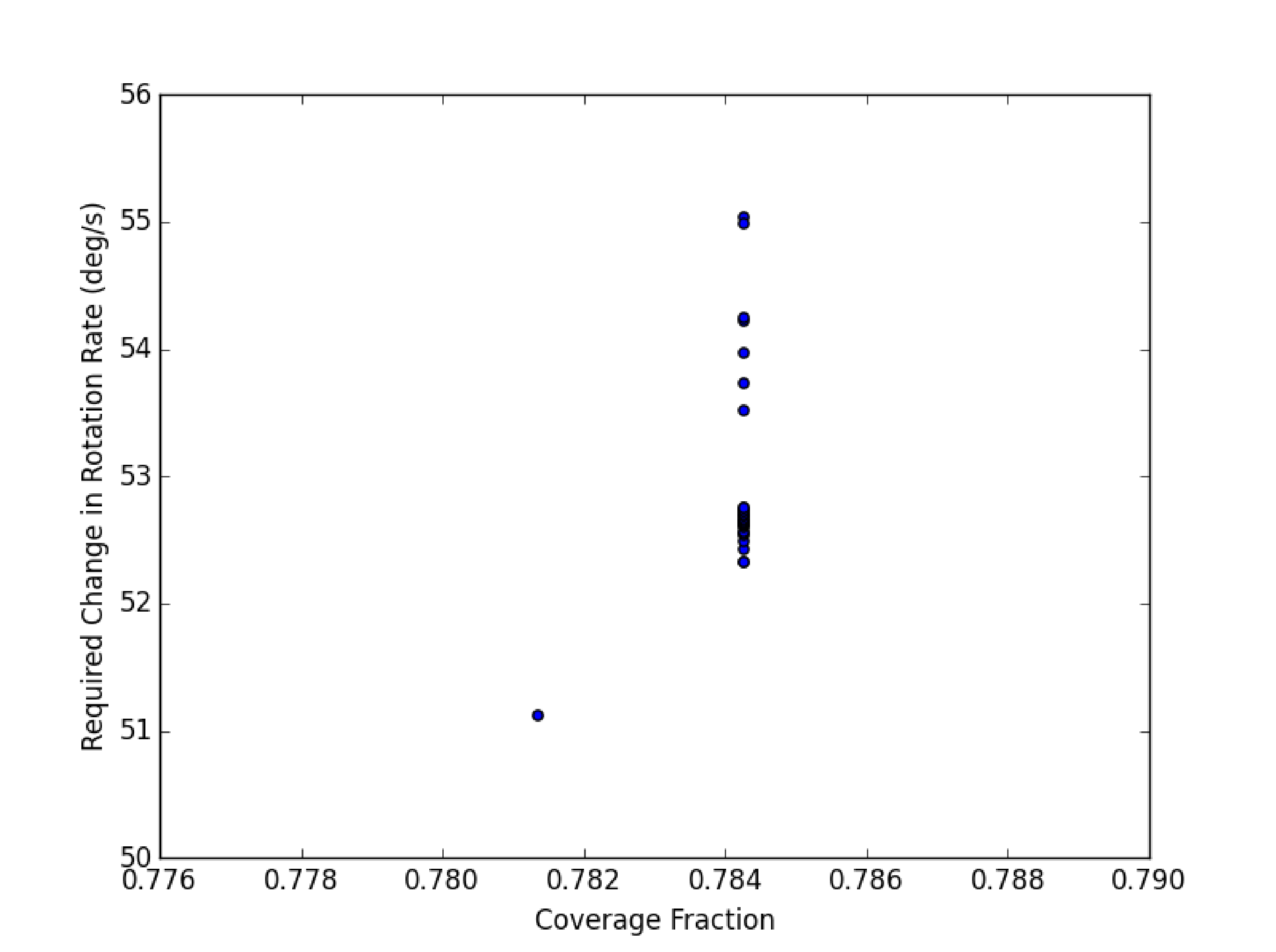


RESULTS



Coverage: 24.2832%
Change in rotation rate: 58.8 degrees/s

RESULTS



1750 generation

CONCLUSION

- This implementation of NSGA-2 produced a set of non-dominated solutions that are able to recover 96.2% of the possibly covered area
- This is intended as the inner-loop solver for a Multi-Objective Hybrid Optimal Control Algorithm where the outer-loop optimizes trajectories and the inner-loop optimizes observation schedules for those trajectories
  - This would be a Hybrid Optimal Control architecture where both the inner and outer loops are multi-objective
  - The optimized trajectories alter the bounded possibilities of the inner loop so as to provide the potential for greater coverage and lessened attitude control effort