ENTRY TRAJECTORY PLANNER FOR HIGH ELEVATION MARS LANDING. A. Bombelli¹, L. Soler² and K. Mease¹, ¹ University of California, Irvine, CA 92697 anbombeell@uci.edu, ² University of California, Irvine, CA 92697 kluis@uci.edu, ¹University of California, Irvine, CA 92697 kmease@uci.edu.

Introduction: Future missions to Mars present new entry guidance challenges such as decelerating heavier spacecraft and landing at higher elevations. For the Mars Science Laboratory (MSL) [1], [2] mission, feedback entry guidance [1] steered the heaviest Mars entry vehicle to date, a nearly 3.6 metric ton vehicle, to a landing site with elevation −4.5 km MOLA. The predicted 3σ landing error ellipse was 25 by 20 km, small enough to target the scientifically desirable Gale Crater. For MSL a reference entry trajectory was planned in advance, serving as the basis for an on-board neighboring trajectory guidance algorithm that issued bank angle steering commands to the attitude control system.

In this paper, an alternative entry trajectory planner for Mars missions targeting higher elevation landing sites is proposed. Landing site elevations of +2 km MOLA or greater are desired to explore the Ancient Highlands. The planner assumes a carefully designed, parametrized bank profile with a similar number of parameters to the MSL planner [1]. The parametrization is designed to resemble optimal bank profiles and the planner performance is characterized by direct comparison to the optimal trajectories.

Vehicle Performance: The entry planner determines a bank angle profile that steers the vehicle to a specified downrange-crossrange and a final state compatible with supersonic parachute deployment. The first step in developing a high elevation trajectory planner is to determine the entry vehicle performance capability. Trajectory optimization serves this purpose.

Given an atmospheric entry point, we first compute the feasible set, i.e., the set of final states reachable with a trajectory satisfying all control constraints and intersecting the parachute deployment window [3]. Then we compute trajectories that minimize a dual-objective performance index aimed at obtaining a final altitude as high as possible while preserving control authority so that the trajectory is flyable in the presence of dispersions. Soft constraints are imposed on the optimal bank angle profile to leave margin for tracking purposes.

Trajectory planner: Based on the optimal bank profiles, a piecewise constant bank angle profile, with 4 segments and a bank reversal between the second and third segment, is proposed. The full 3 DOF point mass dynamics are considered in the planning. To obtain a bank profile satisfying the constraints on bank angle and its derivatives, second-order dynamics are imposed on bank acceleration. Three parameters, namely the times to switch between the 4 segments, are optimized. The on-board planning problem takes the form of a constrained parameter optimization problem, i.e., a nonlinear programming problem. To assess the planner formulation, the problem is solved by a Nelder-Mead, i.e. downhill simplex, method [4].

Results and Conclusions: The numerical results are based on data for an MSL-type vehicle. Comparison of the optimal trajectories with the planned trajectories shows that the low-order parametrization achieves near-optimal performance to sites in the central portion of the landing footprint for a given entry state. Thus the planner generates a trajectory within the performance capabilities of the vehicle that has a high parachute deployment altitude without sacrificing too much control authority.

We envision that the planner could be used on-board and executed just prior to entry or even during entry. Future work is needed to determine a fast and reliable method for solving the nonlinear programming problem that is suitable for on-board execution.