Plume Impingement Induced Surface Erosion During Retro-Propulsive Landings on Mars. A. Sengupta[2], M. Mehta and J. Vizcaino[2], P. Metzger[3],[1] Jet Propulsion Laboratory, 4800 oak Grove Dr., Pasadena CA 91109, anita.sengupta@jpl.nasa.gov, [2] NASA Marshall Space Flight Center, Huntsville, AL., [3] NASA Kennedy Space Center Cape Canaveral, FL.

Introduction: The quantification of the environment that occurs as a result of the engine plumes impinging the soil during landings on Mars is critical for robotic and human landed mission architectures. The granular flow that results from the impinging supersonic, under-expanded exhaust jets can result in soil liquefaction. The aerodynamic environment that results from the reflected plumes results in dust lifting and saltation. Both create a potentially erosive contamination environment for the surface payload. The landing site alteration studies of the Viking era indicated that engine plume impingement could result in soil bearing capacity failure and eruptions following engine shutdown. They discovered highly volatile soil mechanics that necessitated a change in nozzle design to reduce surface impingement pressure (below 2000 Pa). Similarly, landing site alteration studies for the Phoenix mission indicated surface impingement pressure in excess of 10 kPa, which resulted in significant soil erosion. Most recently, the landing of Curiosity, which significantly increased the distance between the nozzle exit plane and surface via the sky-crane, still resulted in significant surface erosion and particle lifting during the terminal descent and landing.

This research concerns the development of a semi-empirical engineering model to predict erosion and deposition rates, crater geometry and particulate trajectories in this energetic environment. Computational fluid dynamics simulations of the plumes will define pressure, velocity, and temperature profiles at the impingement site and in the reflected region. Experimental and flight data from Viking, Phoenix, and Curiosity are used to develop non-dimensional scaling laws over a range of conditions and parameters including soil media type, surface impingement and atmospheric pressures, thruster aerodynamics parameters, and non-dimensionalized altitude. Specifically Digital Elevation Models (DEMs) of the plume-induced cratered sites of Phoenix and Curiosity will be evaluated for quantification of surface erosion during landing (Figure 1). Comparison of modeling to test data and mathematical techniques will be discussed.

[1] Manish Mehta, Anita Sengupta, Nilton O. Renno, John W. Van Norman, Peter G. Huseman, Douglas S. Gulick, and Mark Pokora. (2013). “Thruster Plume Surface Interactions: Applications for Spacecraft Landings on Planetary Bodies” AIAA Journal, doi: 10.2514/1.J052408.

[2] M. Mehta, N.O. Renno, J. Marshall, M.R. Grover, C. Woosley, N. Rusche, J.F. Kok, A. Sengupta, R. Hryciw, Y.S. Jung, P.H. Smith, "Explosive Erosion During Phoenix Landing Exposes Subsurface ice on Mars," Icarus, Volume 211, Issue 1, Jan 2011.

[3] A. Sengupta, J. Kulleck, S. Sell, M. Mehta, M. Pokora, J. Van Norman, “Mars Lander Engine Plume Impingement Environment of the Mars Science Laboratory,” Proc. of the IEEE 2009 Aero Con, March 2009.

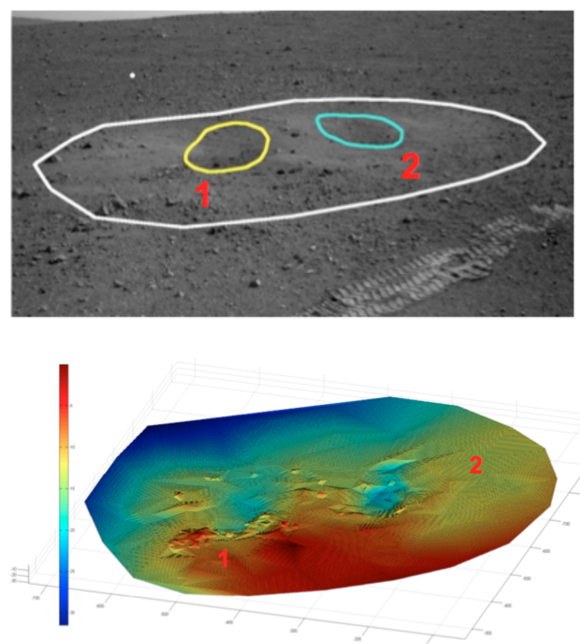

Figure 1. Reconstruction of Erode surface from MSL landing using image processing techniques.