THE ENGINEERING BEHIND MARS EXPLORATION PROGRAM 2007 PHOENIX MISSION LANDING SITE SELECTION, J. Guinn[1], G. Bonfiglio[1], L. Craig[1], P. Desai[3], M. Garcia[1], R. Grover[1], T. J. Parker[1], J. Prince[3], K. Seelos[3], R. Shotwell[1], E. Slimko[1], [1]Jet Propulsion Laboratory, Pasadena, CA 91109, joe.gunn@jpl.nasa.gov, [3]Langley Research Center, VA, [3]Washington University, St. Louis, MO 63130

Introduction: Several engineering problems must be addressed to ensure the Phoenix landing site is properly selected. The size of the possible landing area is driven largely by the entry flight path angle and the accuracy of the delivery at the top of the atmosphere. Once entering the Martian atmosphere, additional uncertainties such as the air density, winds, lander attitude control and center-of-gravity offset contribute to the overall landing dispersions. As touch down occurs, the performance of the landing RADAR, IMU, thrusters and robustness of the lander structure to slopes and rocks drive safety concerns. This abstract details the engineering processes used in the overall landing site selection and certification process.

Landing Site Targeting: The first step in analyzing landing safety is to produce a descent trajectory that is consistent with an Earth-to-Mars transfer. The Phoenix mission design team developed several interplanetary trajectories that launch during a 22-day period in August 2007 and arrive at Mars in late May 2008 (late Mars spring). Each trajectory arrives with slightly different geometry and delivery uncertainty. Each of these trajectories, are propagated to the surface with 2000 Monte-Carlo variations in delivery accuracy and atmospheric model parameters resulting in dispersed landing locations contained within a longitude/latitude box of 150 km by 75 km.

Entry, Descent, and Landing (EDL): Steeper entry flight path angles result in smaller landing dispersions. However, the steeper the entry, the lower the margins of safety. Margins on items such as the parachute deployment Mach number and the time from parachute deployment to lander separation approach unacceptable limits at entry flight path angles steeper than minus 13 degrees. Currently, the entry vehicle has no center-of-gravity (CG) offset. When a CG offset exists, trajectory lifting is possible and larger landing dispersions result. Atmospheric density and wind model uncertainties, derived from Mars Global Climate Models and Thermal Emission Spectrometer (TES) data from the Mars Global Surveyor (MGS) Orbiter [1], make up the remainder of the dispersion contributions.

Touch Down Safety – The Known: Fortunately, the northern plains of Mars are very flat and low. The surface elevation over "safe" areas of the candidate boxes is about -4.2 km [2]. "Safe" here means areas without visible geomorphologic hazards or slopes greater than 16 degrees. Actual slopes appear to be very benign. Analysis of Mars Orbiter Laser Altimeter (MOLA) measurements [2] show slopes are below four degrees at scales of 100 m. While there are no data at lander scales, analyses using MGS stereo Mars Orbiter Camera (MOC) images [3] has been used to confirm small slopes at lengths scales of about 10 m. The surface material exhibits moderate reflectivity that poses no spoofing danger to the lander RADAR.

Touch Down Safety – The Unknown: Rock distribution remains the least understood safety hazard. Large rock distributions (i.e., > 5 m) have been analyzed using MOC Narrow Angle data [4]. The distributions are at such low probabilities they are not considered hazardous. The lack of high spatial resolution remote sensing, combined with the fact that thermal inertias cannot be relied upon for rock abundance estimates at these latitudes, makes it impossible to directly estimate the distributions of rocks smaller than 5 m at this time. In fall of 2006, the Mars Reconnaissance Orbiter will begin to observe candidate Phoenix landing sites with the HiRISE imaging system. This will provide estimates of meter scale rocks distributions that can be used for touch down safety analyses.

Landing Site Selection and Certification Process: The process of site selection and certification merges both science and engineering safety requirements. Several regions 20 deg by 7 deg (about 400 km square) were initially evaluated. Since there were no clear engineering safety discriminators, the primary criteria used to down select the region (ice depth) was driven by science [5]. All regions were found to be acceptable in terms of: site altitude, slope, atmospheric dynamics, surface reflectivity, thermal inertia, and albedo.

Within the remaining region, three sites were recently selected for further study. MRO and other remote sensing observations will be collected in boxes 150 km by 75 km centered on these sites during the upcoming northern summer. In addition, Digital Elevation Models (DEMs) generated from stereo MOC images [3] will be used for high fidelity RADAR and touch down analyses. Rock contact analyses will be updated using special simulation tools and refined rock distribution estimates from MRO HiRise images and Mars Odyssey bi-static RADAR measurements [6]. The results will be used to identify the best site that minimizes landing safety risks.

Landing Site Selection Timing: Launch preparations require the region to be selected one year before liftoff. The final site selection is needed six weeks prior launch to prepare for the first post-launch Trajectory Correction Maneuver (TCM). No propellant has been allocated for landing site changes post-launch. Propellant costs to change regions at the first TCM (L+10 days) are significant and only possible if a favorable launch results in extra fuel availability. Landing site changes within the selected region can be performed for much less propellant. There are a total of six TCMs planned during the interplanetary passage. Landing site changes within the region will be considered for risk reduction only if there are sufficient propellant reserves.

References: [1] Arvdison et al., (2005) *AGU Fall Meeting*. [2] Deal and Arvidson (2006) *LPSC XXXVII this issue.*. [3] Kirk et al., (2006) *LPSC XXXVII this issue*. [4] Golombek et al., (2006) *LPSC XXXVII this issue*. [5] Arvdison et al., (2006) *LPSC XXXVII this issue*. [6] Callas et al., (2006) *LPSC XXXVII this issue*

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