**ALBEDO CHANGES AT MARTIAN LANDING SITES.** I. J. Daubar[1], A. S. McEwen[2], and M. P. Golombek[1]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 (ingrid.daubar@jpl.nasa.gov), [2]Lunar and Planetary Lab, University of Arizona, Tucson, AZ 85721.

**Introduction:** Spacecraft that land in dusty areas of Mars create low-albedo patterns around the landing site (Fig. 1), not unlike "blast zones" (BZs) around new impacts where high-albedo dust is disturbed or removed [1]. We measure brightening of these albedo patterns using the same methodology as [1] to estimate lifetimes for these features. The amount of initial darkening and rate of subsequent brightening (return to surrounding albedo) is also relevant to the future InSight Discovery mission [2] due to the thermal effect of the changing surface albedo on the Heat Flow and Physical Properties Package ($HP^3$) instrument [3].

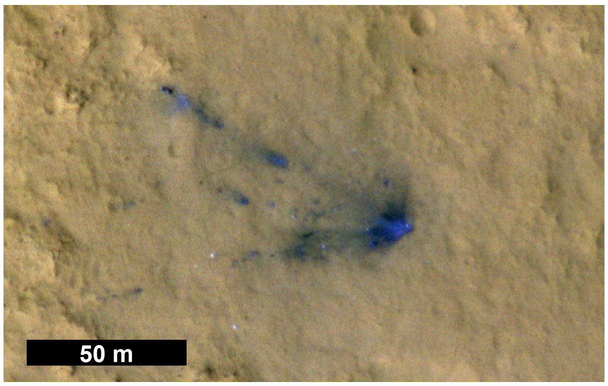


*Figure 1: Low-albedo area around MSL descent stage landing site imaged shortly after landing. HiRISE enhanced color RDR ESP_029957_1755 taken 16 Dec 2012. Image credit: NASA/JPL/University of Arizona.*

**Method:** We used repeat images taken by the High Resolution Imaging Science Experiment (HiRISE) [4] over the landing sites of the Mars Science Laboratory (MSL) [5] and Phoenix [6] missions. Ideally these images are taken at the same time of the martian year to avoid seasonal variations in the real surface albedo and changing viewing conditions. This is an important consideration for the Phoenix landing site at latitude 68°N, where polar processes affect the surface on seasonal timescales. However, to investigate changes that occur on timescales on the order of a martian year, we must include images taken at different seasons. Viewing geometries also could not always be matched precisely due to the limitation of spacecraft observing opportunities, but the relative albedo method described here alleviates the variation between images due to differing solar incidence angles.

HiRISE images were analyzed using the freely available HiView software [7], an image viewing and analysis application that supports the JPEG2000 format of HiRISE data. Representative regions within the low-albedo features were sampled in the RED (570-830 nm) HiRISE RDR products to get the mean pixel data number (DN) values. Samples were chosen to include areas uniformly darkened by the landing event and to exclude variations in topography or geographic features that would create shadows, apparent albedo differences, or otherwise complicate measurements. The same procedure was performed for a background (bg) sample far from the landing site. First-order atmospheric effects were removed by subtracting the minimum DN in the image, which should be located in a shadow. This has a value of 3 in all cases due to the stretch applied to all HiRISE RDRs. Relative albedos were calculated:

$$A_{rel}=A_{sample}/A_{bg}=(DN_{sample}-DN_{dark})/(DN_{bg}-DN_{dark})$$

Such relative albedos are more accurate than absolute albedos, because to first order they eliminate the effects of differing lighting conditions between images and relieve issues with imperfect radiometric calibration of HiRISE images [8].

The resulting relative albedo was then plotted over time (Figs. 2 and 3). $A_{rel}$~1 before landing, decreases at the time of landing, and gradually increases back toward 1 as the blast zone fades.

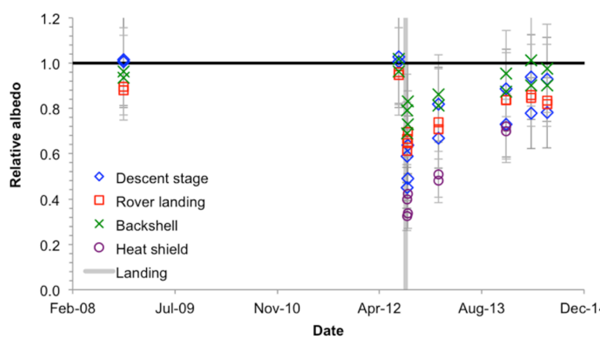


*Figure 2: Relative albedo over time of samples near MSL hardware landing sites. Data to the left of vertical grey line are prior to landing on 6 August 2012. The heat shield was not present in all images, so not all dates have data for those sample locations.*

**Results:** *MSL:* Samples of the MSL landing site were taken at the landing sites of various hardware: the rover, descent stage, backshell, and heat shield. Mechanisms of darkening most likely vary at each of these sites, as reflected by the differing amount of darkening between samples (Fig. 2). Landing reduced the surface albedo ~30-80%, varying by area. A linear brightening model over time is a fairly good match to the data in this case ($R^2$ for fits ranges from 0.87 to 0.99). Rates of brightening are lowest for the lander and backshell sites (~11% $A_{rel}$/Earth year), and higher for the descent stage (~15-18%/yr) and heat shield (22-29%/yr). Projecting such fits forward in time (Fig. 3) results in predicted lifetimes for the various landing site albedo features (Table 1). We predict these features should disappear soon – in fact, regions around the backshell appear to have already returned to close to the background albedo in the most recent image dated June 2014, which was predicted by our estimated lifetimes.

We will be requesting another image of the landing area to test the rest of our predictions, and to test the validity of the linear fading model.

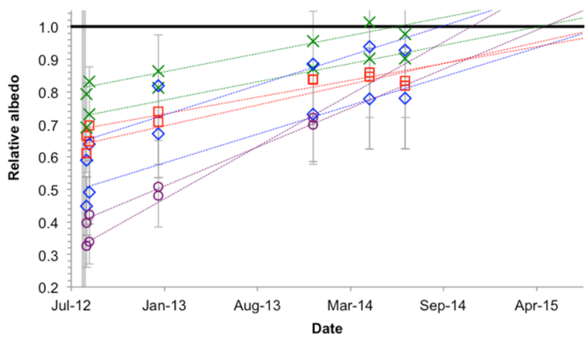


***Figure 3:*** *Linear fits to relative albedo over time at MSL hardware sites, yielding the estimated lifetimes shown in Table 1. Symbols same as in Fig. 2.*

***Table 1:*** *Estimated fading/brightening lifetimes for low-albedo features around MSL hardware landing sites.*

| Hardware landing sample | Estimated lifetime (days) | Estimated Lifetime (Mars years) | When will /did feature disappear? |
|---|---|---|---|
| Descent 1 | 1,120 | 1.6 | 8/31/15 |
| Descent 2 | 767 | 1.1 | 9/11/14 |
| Rover 1 | 1,211 | 1.8 | 11/30/15 |
| Rover 2 | 1,124 | 1.6 | 9/4/15 |
| Backshell 1 | 976 | 1.4 | 4/9/15 |
| Backshell 2 | 671 | 1.0 | 6/7/14 |
| Heatshield1 | 832 | 1.2 | 11/16/14 |
| Heatshield2 | 990 | 1.4 | 4/23/15 |
| **Average** | **961** | **1.4** | **3/25/15** |

*Phoenix:* The Phoenix site is more complicated: the surface is lower in albedo, thus subtle changes are more prone to measurement uncertainty. Atmospheric hazes are common at that latitude [*e.g.* 9], and seasonal processes can affect the surface albedo as well as gradual brightening due to airfall of dust. We can generally conclude that the landing reduced the surface albedo to ~60-80% of pre-landing albedo, and it subsequently re-brightened within one martian year (Fig. 4).

The landing mechanism of Phoenix is similar to that of InSight, although the surrounding surface characteristics and effects of seasonal processes will differ.

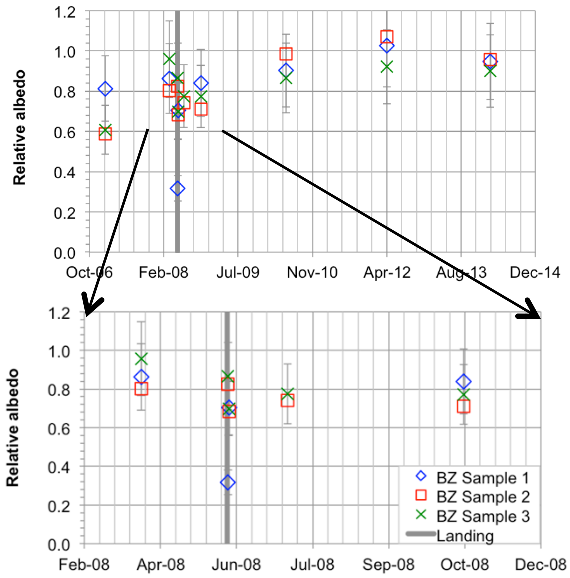


***Figure 4:*** *Relative albedo over time of samples of the Phoenix landing site. Data to the left of vertical grey line are prior to landing on 25 May 2008. Bottom plot shows a zoom in time of the top plot.*

**Conclusions:** At both the MSL and Phoenix landing sites, quantifiable darkening occurred at the time of landing that brightened/will brighten back to the background albedo within a few years. In the case of Phoenix, seasonal processes most likely were responsible for erasing the albedo signature of landing after one martian year. For MSL, the amount of darkening and rate of brightening varies between hardware locations, thus presumably they depend on differing mechanisms and/or energies involved in the features' formation.

These lifetimes are shorter in general than those of BZs around new, dated impact craters [1]. Although they have a large spread in values, the median lifetime is ~7 Mars years, and the shortest lifetime estimated for any new crater BZ is 1.2 Mars years. Their longer lifetimes relative to spacecraft BZs may be due to the higher energy of crater-forming impacts compared to decelerated spacecraft.

**References:** [1] Daubar *et al.* (2014) *45th LPSC*, Abstract #2762. [2] Banerdt *et al.* (2012) *43rd LPSC*, Abstract #2838. [3] Spohn *et al.* (2014) *45th LPSC*, Abstract #1916. [4] McEwen *et al.* (2007) *JGR* 112, 5. [5] Grotzinger *et al.* (2012) *SSR* 170, 5-56. [6] Smith *et al.* (2008) *JGR* 113, E00A18. [7] www.uahirise.org/hiview [8] Delamere *et al.* (2010) *Icarus* 205, 38-52. [9] Tamppari *et al.* (2008) *JGR* 113, E00A20.