LANDING SITE SELECTION FOR THE SPACEIL MISSION TO THE MOON.

Y. Grossman, O. Aharonson and A. Novoselsky, Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel

Introduction: SpaceIL is an Israeli mission aiming to land a spacecraft on the surface of the Moon as part of the Google Lunar XPrize. In addition to the competition-mandated requirements, the mission includes a scientific payload with the primary objective of characterizing the magnetism of the lunar crust. Measurements by the SpaceIL magnetometer (SILMAG) will be performed in orbit, during landing, and on the surface. We present here the selection and characterization process employed in identifying potential landing sites for this mission.

Strategy: The process we followed for identification of potential landing sites consists of three steps: (1) Using global data sets to generate a map of locations on the Moon verified to satisfy prescribed engineering constraints. (2) Sorting and down-selecting to a set of ~10 potential sites. (3) Detailed analysis of select sites.

Global Analysis: The size of a landing site is currently defined as 15 km in diameter. The landing ellipse is expected to be narrower along one axis, but the approach direction is not yet known. We used five global data sets in order to verify corresponding landing constraints: rock abundance, topographic variation, albedo, slopes, and surface roughness. The analysis was performed on data gridded at 16 pixel/deg, and the maps were scanned for locations where circular regions of diameter 15 km include >95% area that is verified to meet all five criteria.

Rock Abundance: We avoid landing near rocks and boulders of 10 cm scale, defined by spacecraft engineering constraints. The LRO Diviner Radiometer provides rock abundance estimates by modeling the surface temperature variations [1]. These variations are sensitive to rocks on the scale estimated to be ~50 cm. We extrapolate down to 10 cm using the particle size distribution of [2], derived from imaging at the Surveyor landing sites.

Maximum topographic variation: The landing system design limits the maximum topographic variations allowed within the landing ellipse. We use the Selene-LOLA derived elevation model SLDEM [3] to impose a criterion of maximum variation from peak to peak.

Albedo at wavelength 1548 nm. Spacecraft navigation employs a laser altimeter, imposing a minimum reflectance requirement. We use data acquired by the Selene Multiband Imager Near InfraRed instrument, in the 1548 nm channel.

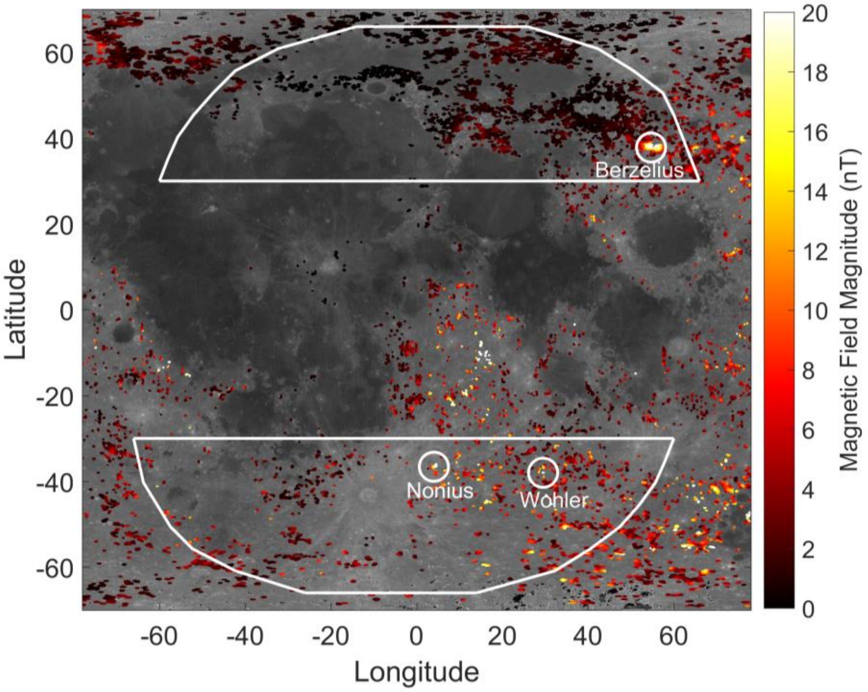

Figure 1: Map of the distribution of SpaceIL potential landing sites, showing locations verified to meet engineering constraints, as well as three candidate sites undergoing detailed analysis.

Surface slopes: Landing safety considerations limit regional bidirectional slopes. We use slopes from LRO LOLA altimetry data [4,5]. The baseline varies from 30 to 120 meters and the data are binned in areas ~(2 km)^2.

Surface Roughness: Landing safety considerations limit the allowed surface roughness. We use LRO LOLA derived values, based on root mean square (RMS) of altitude departures from planar fit to consecutive data points [5]. Here again, the baseline varies from 30 to 120 meters and the data are binned in areas ~(2 km)^2.

Figure 1 shows the resulting map of location verified to meet the engineering constraints. Surface temperature and communication consideration limit landing latitude and longitude further, as shown in the white boundary.

Sorting and Down-selecting: Recognizing the scientific objective of characterizing the crustal magnetic field, we now sort and down-select landing sites from among the available set. In Figure 1, locations meeting the constraints are shown, with color indicating the magnitude of the local magnetic field, derived from Lunar Prospector Magnetometer and Selene LMAG data. Tsunakawa et al. [6] used surface vector mapping method in order to create the global surface magnetic field map used here.

We sort the acceptable sites according to topographic variation and magnitude of the magnetic field, and within a preferred site, optimize the landing ellipse localization according to a map of slope values at high resolution (60 m/pixel).

Detailed Analysis: We focus on three select sites for detailed analysis. For all sites 60 m/pixel topographic grids [3] were analyzed. Where available, LROC Narrow Angle Camera (NAC) image stereo pairs were used to generate topographic grids at a resolution of 2 m/pixel using SOCET SET [7]. Slope distributions were computed from these models. We extracted all relevant LROC NAC images for each site, creating image mosaics and coverage maps of the sites.

Figure 2 shows a possible landing ellipse near Berzelius crater. The SLDEM topography is shown in color, along with LROC stereo high resolution topography superimposed. Contours indicate the magnetic field amplitude as described above.

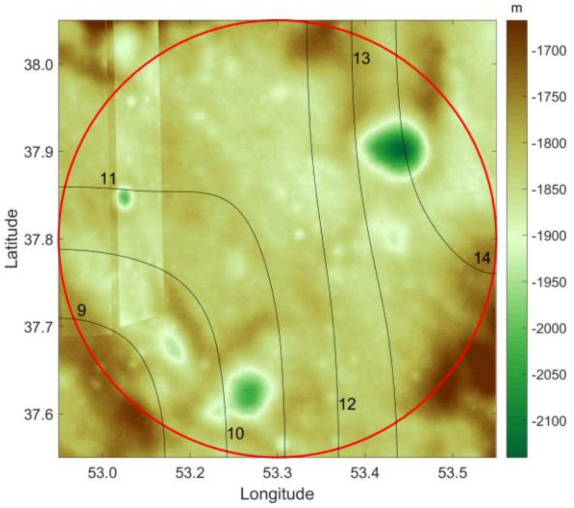

Figure 2: Candidate SpaceIL landing site near Berzelius crater. Topography from SLDEM (60 m/pixel) and local DEM derived from LROC NAC stereo pairs. The contours represent magnitude of the surface magnetic field from [6].

Acknowledgements: We are thankful for support from the Adolf and Mary Mil Foundation, the Helen Kimmel Center for Planetary Science, the ISF I-CORE program Origins: From the Big Bang to Planets, and from the Minerva Center grant.

References: **[1]** Bandfield, J. L. et al. (2011), *J. Geophys. Res.*, 116, E00H02. **[2]** Shoemaker, E. M. and Morris, E. C. (1970), *Radio Sci.* 5, 129–155. **[3]** Barker, M. K. et al. (2016), *Icarus*, 273, 346-355. **[4]** Smith et al. (2010), *Space Sci. Rev.* 150:209. **[5]** Rosenburg, M. A. et al. (2011), *J. Geophys. Res.*, 116, E02001. **[6]** Tsunakawa, H., F et al. (2015), *J. Geophys. Res.*, 120, 1160–1185. **[7]** Tran T. et al. (2010), *41st LPSC*, Abstract #2515.