A ROBOTIC SAMPLE RETURN MISSION TO THE NORTHERN PORTION OF THE SCHRÖDINGER BASIN PEAK RING. N. M. Curran[1], A. L. Gullikson[2], N. J. Potts[3,4], J. K. Dhaliwal[5], M. Leader[6], R. Rege[7], and D. A. Kring[8], [1]SEAES, University of Manchester, Oxford Road, M13 9PL, UK (natalie.curran@manchester.ac.uk), [2]Northern Arizona University, USA, [3]The Open University, UK, [4]Vrije University, Amsterdam, [5]Scripps Institute of Oceanography, UC San Diego, USA, [6]University of Texas at Austin, USA, [7]Columbia University, USA, [8]Lunar and Planetary Institute (LPI), TX, USA.

Introduction: In 2007, the National Research Council identified 8 major concepts and 35 prioritized science goals for exploration of the Moon [1]. From 2008-2012, a series of summer studies determined the lunar surface locations where each of those concepts could be addressed [2]. The Schrödinger basin emerged as one of the most scientifically interesting locations. A recent study [3] identified three potential landing sites within Schrödinger for human exploration. Here, we investigate landing sites for a robotic lander that might be used in a human-assisted sample return mission [4].

Schrödinger basin: Schrödinger basin (Fig 1), situated on the lunar farside, is the second youngest basin on the Moon, located in the largest and oldest South Pole-Aitkin basin. Thus, samples returned from this region have the potential to constrain the duration of the entire basin forming epoch, including the age of the oldest event, and test the lunar cataclysm hypothesis, which are the two highest science priorities [1]. Schrödinger has a diameter of ~320 km [5], an average depth of 4.5 km, and is centred at 75°S, 132.5°E [6]. The peak ring is ~150 km in diameter and rises 1 to 2.5 km above the basin floor [7]. There are also two volcanic units located within the basin.

A landing site adjacent to the northern peak-ring provides access to a number of the lithologies mentioned above, that can address many of the NRC (2007) scientific goals. There is the potential to collect samples of Schrödinger impact melt and breccia, a mare-type basaltic unit, and uplifted crustal material (Fig 2). A deep, 50 km long fracture is also accessible within the area.

Methods: Traverse maps were generated using a number of tools combined in ArcGIS software. The basemap consisted of a WAC (wide angle camera) image of Schrödinger overlain with NAC (narrow angle camera) images, all products of the Lunar Reconnaissance Orbiter Camera. The high resolution of the NAC images (0.5 m per pixel) allowed exposed bedrock at station localities to be identified for sampling. LOLA (Lunar Orniter Laser Altimeter) data was utilized by using a Digital Elevation Model to interpolate a slope graph for the region. Spectral reflectance data [6] from the Moon Mineralogy Mapper (M^3) was also intergrated with geological maps of Schrödinger [6, 8, 9]. Landing sites (also the location of Station 1) were chosen on the basis of slope (e.g., 0-2°) and taking into account a ~200 m landing accuracy previously demonstrated by Apollo 12 [10]).

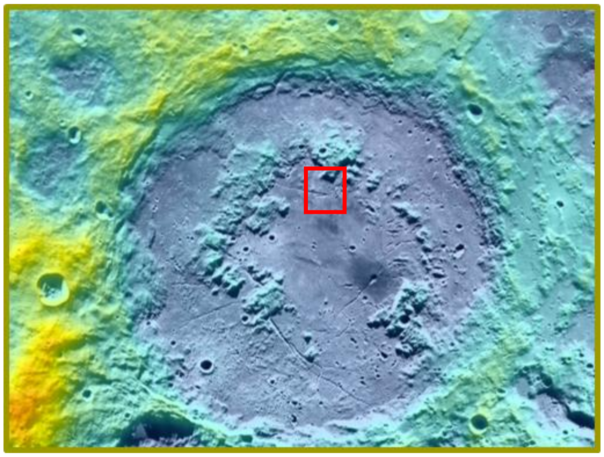

Fig. 1: WAC image of Schrödinger basin, box indicates the limits of the Northern Peak-ring site.

Rover Capabilities and Operations: We have assumed that the theoretical rover has the ability to travel at Lunakhod 1 and 2 speeds of 1-2 km/hr. Traverse slopes up to 16° were considered feasible based on the capabilities of the Apollo Lunar Roving Vehicle. A model was derived (discussed here [11]) to analyze the selected traverse routes, taking into consideration the slope of this route, and providing an accurate prediction of the time it would take the rover to travel between stations.

Experimental and theoretical data were used to develop a concept of operation (ConOps) to determine the amount of time required by the rover to work at each station. This included a 51 hour start up time, 53 hours of rover pack down at the lunar lander for sample return, and 27 hours at each station along the traverse.

Optimum Traverse. The optimum traverse is a 5-station, 13.7 km route. Rover ConOps, speed, and variations in slope (which do not exceed 14.1°) require 10.7 days to travel to and sample material at each station (Fig 2).

The first sampling station is at the landing site (LS – Fig 2), located on a mare unit believed to be younger in age than previously sampled Apollo and Luna mare basalts [8]. The regolith here should be dominated by the underlying basaltic material, similar to the situation at the Apollo 11 landing site [12]. Station 2 provides access to material in the Schrödinger melt sheet that have relatively glass-rich spectra [6]. Stations 3 and 4 focus on samples of Schrödinger impact breccia and uplifted crustal rocks, respectively. An ejecta blanket from a young ~80 m crater in the vicinity of station 3 exposes fresh samples of this brecciated impact melt material. The crustal rocks at station 4 are located at the bottom of the ~1.5 km high peak ring. Station 5 is positioned on the edge of the deep fracture, 40 m above the fracture floor. Samples can be collected from this height using a tether attached to the rover [13].

In theory this traverse could provide insight into the thermal and magmatic evolution of the Moon and a window into the farside lunar mantle. Furthermore, rocks collected from stations 3, 4, and 5 offer the opportunity to examine a diverse set of crustal and possible mantle lithologies, adding to our understanding of the lunar magma ocean cumulate pile. Multiple samples of Schrödinger melt material can also be collected. Determining the age of samples from this melt sheet would provide an age for the Schrödinger impact event, constraining the end of the basin forming epoch. Sampling the deep fracture could provide insight into the volatile component of the lunar poles as illumination data [14] indicates the walls of the fracture produces areas of permanent shadow. Additionally, cratering and regolith processes can be investigated at all stations to help further understand the surface modification processes on an airless body [15].

Descoped Traverses. If a shorter distance and/or duration is required, there are two descoped options. The optimum traverse can be shortened to 3 stations over a distance of only 3.2 km that takes 7.8 days to complete. The slope of this traverse does not exceed 6.5° and has an average of 2.2°. The focus here would be to collect samples of the mare lithology and Schrödinger impact melt (stations 1 and 2 in the optimum traverse). An additional station would be added, sampling an orthopyroxene-bearing (possibly noritic [6]) lithology of the deep fracture, similar to station 5 on the optimum traverse. As this is a descoped mission scenario, the potential to collect multiple samples of uplifted crustal material directly from the peak ring is lost.

Alternatively, the landing site could be moved north-west of the optimum traverse in order to investigate the highest scientific concepts of the NRC report. In this case, the traverse would be 12.7 km long, taking a total of 10.2 days to complete. The average slope of the traverse is 7.1° and reaches a maximum of 15.7° as the rover arrives at the base of the peak ring. The traverse focuses on returning samples to determine the age of the Schrödinger impact event and collect samples from the peak ring. However, the opportunity to sample farside mare material is lost.

Conclusion: This study highlights that sampling multiple lithologies from the northern portion of Schrödinger basin can be achieved by a robotic asset within a single period of lunar illumination (14 Earth days). Descope mission scenarios with shorter distances and duration exist in the area, but these missions will not accomplish the same amount of science goals as the optimum traverse.

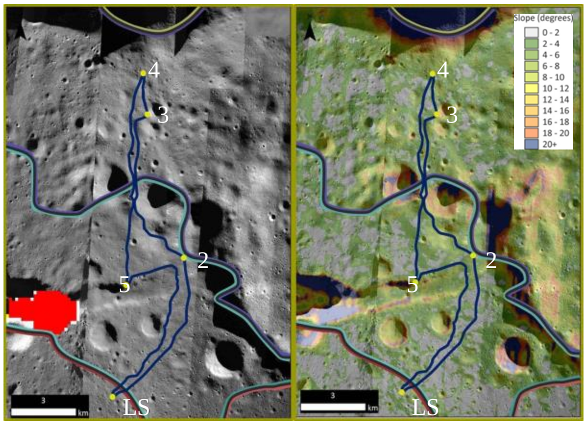

Fig. 2: A close up ArcGIS image of the Long Optimum traverse showing a) geological boundaries and M^3 data from [8] and b) the slope map for the same region.

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References: [1] NRC. (2007) Final report. [2] Kring D. A. and Durda D. D. (2012) *LPI Contrib*. No. 1694, 688. [3] O'Sullivan K. M. et al. (2011) *GCA Spec. Pap*., 477, 117-127. [4] Burns J.O. et al. (2013) *J. Adv. Space Res*., 52, 306-320. [5] Spudis P. D. (1993) *Camb. Planet. ScI.* [6] Kramer G. Y. et al. (2013) *Icarus*, 223, 131-148. [7] Kring D. A. et al. (2013) *LMI V*, Abstract# 3069. [8] Shoemaker E. M. et al. (1994) *Science*, 266, 1851-1854. [9] Mest S. (2011) *Geol. Soc. Am. Spec. Pap.*, 477, 95-115. [10] Spudis P. D. and Pieters C. (1991) Lunar Sourcebook, *Cambridge University Press*. [11] Leader M. K. et al. (2014) *This Conference*. [12] Koretov and Gillis. (2001) *JGR*, 106, 12339-12353. [13] Abad-Manterola, P. et al. (2009) *In Proc. IEEE Areospace Conf., Big Sky, MT*, 1-8. [14] Potts N. J. et al. (2014) *This Conference*. [15] Lucey P. R. et al. (2006) *Rev. Min. & Geochem*, 60, 83-219.