ESTIMATION OF PROBABILITY OF DANGEROUS SLOPES IN THE LANDING SITES OF LUNA-GLOB SPACECRAFT THROUGH ANALYSIS OF SHADOW AREA ON THE LROC NAC IMAGES

S.S. Krasilnikov[1], M.A. Ivanov[1], A.T. Basilevsky[1], A.M. Abdrakhimov[1], A.A. Kokhanov[2]

[1]*Vernadsky Institute of geochemistry an analytical chemistry of RAS, Moscow, Russia; krasilnikovruss@gmail.com*

[2]*Moscow State University of Geodesy and Cartography, Moscow, Russia.*

KEYWORDS:

Moon, Luna-Glob, Luna-25, landing site, LROC NAC, slopes.

ABSTRACT:

Was estimated the probability of encountering of dangerous slopes (>7° on a 3.5-m-baseline) in five landing ellipses of the Luna-Glob (Luna-25) mission. In order to make these estimations, we analyzed dependence between a fraction of a shadowed area on the LROC NAC images and the Sun angle over horizon. We used a high-resolution DTM and the NAC images for the Apollo 16 landing site to calibrate our results and estimate the probabilities of encountering of the slopes in five classes: <7°, 7°–10°, 10°–15°, 15°–20° and >20°.

INTRODUCTION:

During selection of the landing sites, determination of the short baseline slopes is one of the most important tasks. In [1], several high-priority landing sites were selected mostly on the basis of the frequency distribution of slopes on a 60-m-baseline provided by the LOLA instrument [4]. This spatial resolution of the LOLA DTM is rather coarse for a confidential selection of the safe surfaces. In our approach, we first analyzed a dependence between a fraction of a shadowed area on the LROC NAC images and the Sun angle over horizon and then calibrated the results using a high-resolution DTM and the NAC images for the Apollo 16 landing site. Such a procedure allowed estimates of the frequency distribution of the slopes on much shorter baselines, specifically 3.5 m, in five categories: <7°, 7°–10°, 10°–15°, 15°–20° and >20°.

The landing ellipses are in a region between 65-75°S and 0-60°E (fig.1): ellipse 1 is at 68.77° S; 21.21° E, ellipse 4 is at 68.64° S; 11.55° E, and ellipse 6 is at 69.54° S; 43.54°E [1]. Two additional ellipses are in Boguslavsky crate: Boguslawsky-1 (73.9° S; 43.9° E) and Boguslawsky-2 (72.9° S; 41.3° E) [1].

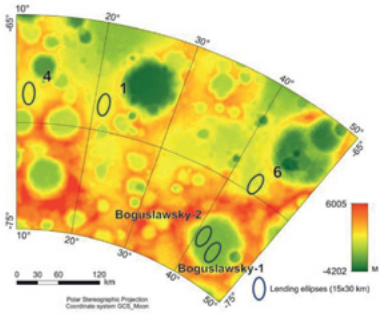

Fig. 1. Several preliminary selected landing ellipses of the Luna-Glob mission.

DEPENDENCE BETWEEN THE SHADOWED AREAS IN THE NAC IMAGES AND REAL AREA WITHIN SPECIFIC RANGE OF SLOPES

Landing site of Apollo 16 was selected for our analysis because this area shows similar morphology and elevation range as the preliminary selected landing sites of the Luna-Glob mission. The analysis of the Apollo 16 landing site was

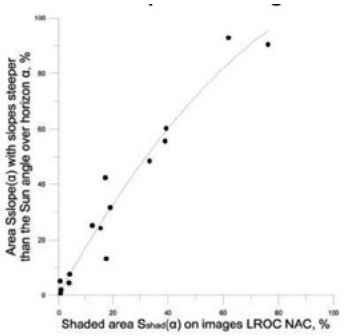

Fig. 2. Dependence of real slopes area more than angle (α) and shadow area on LROC images with the same Sun angle (α).

conducted in two steps. First: we estimated a fraction of the shadowed area on the LROC NAC images as a function of the Sun angle over the horizon. Second: using the high-resolution DTM for the same region, we determined a real area of slopes within specific intervals and compared it with the fraction of the shadowed area estimated at the first step. The least square root approximation of the measured relationship between the area of real slopes steeper than a specific angle (α) and the shadowed area in the image with the same Sun angle (α), defines a calibration curve (fig.2).

ESTIMATION OF SLOPES IN THE POTENTIAL LANDING ELLIPSES OF THE LUNA-GLOB MISSION.

The calibration curve allows estimation of slopes to be made within the Luna-Glob ellipses (fig.3).

Depending upon the local morphologic characteristics of the surface, coefficient of determination (R^2) and mean square error (σ^2) of the calibration curve approximation can vary. Results for the ellipses 1, 4, and Boguslawsky-1, 2 have the higher R^2 and the lower σ^2 (tab.1).

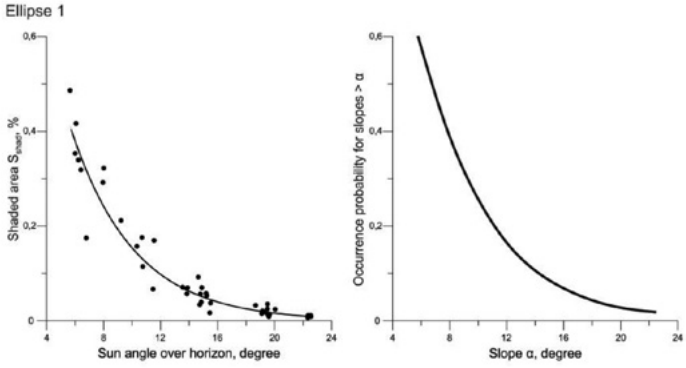

Fig. 3. Ellipse 1. Left – dependence of shadow area on the LROC images and Sun angle. Right – probability of slopes, produced after calibration of left graph.

These values indicate a tight dependence between the shadowed area and the Sun angle; they can be used for more confidential determination of the probability of encounter of the slopes within specific intervals. The low R^2 value

Table 1.

Ellipses	Probability to find the slopes in the classes Вероятность встречи уклонов по классам					R^2	σ^2
	<7°	7°–10°	10°–15°	15°–20°	>20°		
1	0.52	0.22	0.17	0.07	0.02	0.92	0.12
4	0.58	0.19	0.15	0.06	0.02	0.94	0.11
6	0.68	0.15	0.10	0.05	0.02	0.66	0.65
Boguslawsky-1	0.62	0.23	0.11	0.03	0.01	0.97	0.04
Boguslawsky-2	0.62	0.20	0.13	0.04	0.01	0.85	0.24

(0.66) and high of σ^2 value (0.65) characterize ellipse 6 (tab. 1). Low, flattop hills are the most common small-scale topographic features within ellipse 6 [2]. Because of these hills, the areal fraction of shadows varies significantly (tab. 1) but mostly for slopes that are less than 7°. These values, however, are within the safety restrictions of the mission and, thus, ellipse 6 does not appear as a potentially dangerous place to land.

CONCLUSIONS:

Among the five analyzed ellipses, the smallest probability of encountering of slopes higher than 10°, characterizes ellipses number 6, Boguslawsy-1 and Boguslawsky-2 (tab.1). Thus, considering the other criteria for the selection of the landing sites, such as visibility of Earth and the Sun, ellipse 6 appears as the most attractive landing site for the Luna-Glob mission.

It should be emphasized that for ellipse 6, the probability to find the slopes steeper than 10° is relatively high (0.17). To minimize the risk of landing, one can recommend either to re-locate the ellipse or to install an automatic pre-land navigation system in order to avoid dangerous features on the surface (as it realized on Chang'e-3 [3]).

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REFERENCES:

[1] Djachkova M.V., Litvak M.L., Mitrofanov I.G., Sanin A.B. Selection of Luna-25 Landing Sites in the South Polar Region of the Moon // Solar System Research. 2017. V. 51. No. 3. pp. 185-195.
[2] Ivanov M.A., Abdrakhimov A.M., Basilevsky A.T., Demidov N.E., Djachkova M.V., Guseva E.N., Head J.W., Hiesinger H., Kohanov A.A., Krasilnikov S.S., Mitrofanov I.G. Geological characterization of the three high-priority landing sites for the Luna-Glob mission // Planet. Space Sci. 2017 (in press)
[3] Li S., Jiang X. and Tao T. Guidance Summary and Assessment of the Chang'e-3 Powered Descent and Landing // Journ. of Spacecraft and Rockets. 2016. Vol. 53. № 2. p. 258-277.
[4] Smith, D.E., Zuber, M.T., Jackson, G.B. et al (29 others), The Lunar Orbiter Laser Altimeter investigation on the Lunar Reconnaissance Orbiter Mission // Space Sci. Rev. 2010. V. 150. p. 209-241.