SIZE FREQUENCY DISTRIBUTION OF AREAS OF VARIOUS SLOPES AT "FLAT" SITES ON THE SURFACE OF MARS AND THE MOON.

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Introduction: In selection of landing sites on planets and satellites the most attractive are "flat" areas which are close to the targeted objects of the study and have minimum of slopes dangerous for landing. Generally such sites on the planets are at flat plains and flat crater floors. Three Martian 300x300 m sites in areas of work of Viking-1 [1], MSL Curiosity [2], and Spirit [3] and one lunar 2300x4000 m Lunokhod-1 site [4] were studied using different DTMs resolution to eastimate frequencies of the relatively safe areas.

We used DTMs, based on the data acquired from image stereopairs and laser altimeter measurements: LROC NAC images (~0.5 m/px) [5] and LOLA data [6] for the Moon; HiRISE (~0.25 m/px) [7], HRSC (~10 m/px) [8] images and MOLA data [9] for the Mars. The resulted distribution of slopes calculated on the 1, 1.5, 3, and 5 m bases are presented here (Fig. 1, Table 1, see page 2).

Mars: The considered Martian flat sites were formed by combination of the fluvioglacial, impact and aeolian processes.

The site is near Viking-1 landing. Viking-1 landed at the west of Chryse Planitia (22.7 ° N, 48.2 ° W, Jul. 20, 1979), within accumulative plains where several catastrophic flow valleys meet (Kasei, Maumee) [1]. The undulating plains covered with detrital material and dunes are observed in the landing site TV panoramas. From the orbit it is visible that rather smooth plain is pitted with craters and complicated by rare sinuous ridges. Our study showed that the frequences of the area occupied by "safe" slopes <5° at the bases from 1 m to 5 m increase by almost 10% - from 80 to 90% (Fig. 2).

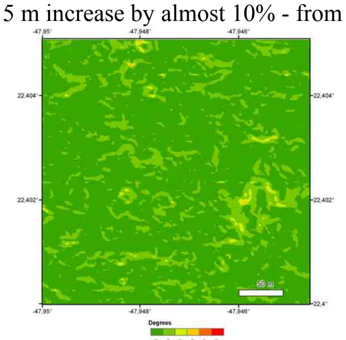

Fig. 2. The Viking-1 area. The slope map, base 1 m. (DTM HiRISE DTEEC_001521_2025_001719_2025_U01)

The site near MSL Curiosity landing. MSL Curiosity landed at the flat N part of floor of the154 km crater Gale (4.5°S 137.4°E, Aug. 6, 2012) [2]. There is a flat accumulative plain, probably a resurfaced floor of former lake. Some small stream valleys cut the northern part of crater rim and open into the crater. The crater central peak (Aeolis Mountain) is surrounding by the field of dunes. The surface is complicated by rare craters, valleys, channels, dunes (Fig. 3). The study of distribution of slopes showed that the estimation of the area occupied by safe slopes <5° at the bases of 1 m to 5 m increases by almost 20% - from 70 to 90%. Dangerous slopes are observed mainly at upper crater wall parts and channel banks.

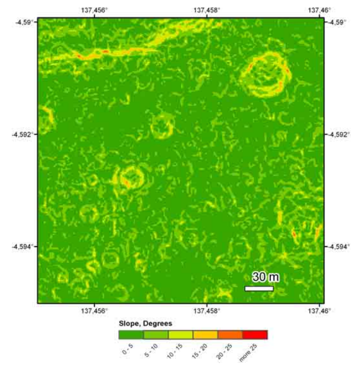

Fig. 3. MSL Curiosity area. The slope map, base 1 m. (DTM HiRISE DTEEC_023957_1755_024023_1755_U01)

The site of Spirit landing. Spirit landed at the flat floor of 170 km Gusev crater (14.57° S, 175.47° E, Jan. 4, 2004) [3]. The crater Gusev is located at NE border of highland Terra Cimmeria area in the mouth of Ma'adim valley, the large 700 km Martian canyon. It is considered that the Gusev floor plain formed by lacustrine deposits from this canyon. The ridge of Columbia hills is placed in the center of the crater. The gently undulated floor plain is disturbed by small craters, and smoothed by aeolian deposits. The surface is covered by boulders and cobbles. Dangerous slopes are observed at upper inner wall parts of 30-40 m craters (Fig. 4). The study of slopes' distribution showed that frequencies of the area occupied by safe slopes <5° at the bases of 1 m to 5 m are estimated as being almost 15% - from 80 to 95%.

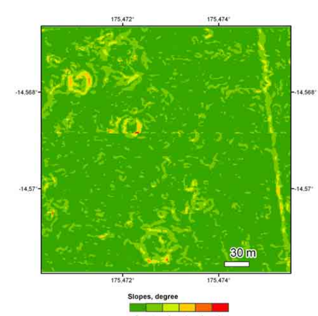

Fig. 4. Spirit area. The slope map, based 1 m. (DTM HiRISE DTEEC_001513_1655_001777_1650_U01)

The Moon: The lunar flat sites are formed by lava emplacement and impact resurfacing.

The area of Lunokhod-1 work. Lunokhod-1 was delivered by Luna-17 probe (38.3 ° N 37.0° W, Nov. 17, 1970), and worked for 11 months in the NW part of Mare Imbrium at the typical cratered mare plain. The considered area is ~ 2 x 4 km [4, 10]. The flat plain was formed by emplacements of basaltic lavas, reworked by meteoritic bombardment. The local relief is complicated only by craters of various sizes and different degrees of maturity. The younger crater, the higher value of the depth-to-diameter ratio H/D> 0.1, and the steeper slopes of crater inner walls [11]. The most dangerous areas with steep slopes are confined to the upper part of the inner walls of the large fresh craters, for example, the 400 m crater in the northern part of the area (Fig. 5). The study of distribution of slopes showed that frequencies of areas occupied by safe slopes <5° from the bases of 1 m to 5 m is estimated as almost 20% - from 60 to 80%.

Conclusions: The considered sites show that the dangerous slopes (>5°) in the considered areas mainly are confined to the upper parts of inner walls of less matured craters. With an increase of the base of slope calculation from 1 to 5 m, the value of safe for landing area with slopes <5° increases by 10-20%. That should be considered for future missions planning for the territories covered by less resolution DTM data.

Acknowledgments: A.T.B., M.A.K., I.P.K. greatly acknowledge being hosted by MIIGAiK and supported by Russian Science Foundation, project 14-22-00197.

References: [1] Stoffen G. A. (1976) *Science, 194,* 4271. 1274-1276. [2] Arvidson R. E. et al. (2014) *JGR,* 119, 1322-1344. [3] Squyres S. H. et al. (2014) *Science*, *305*, 794-799. [4] Karachevtseva I. P. et al. (2014) *PSS, 85,* 175–187. [5] Robinson M. S. et al. (2010) *Space Sci. Rev., 150,* 81-124. [6] Zuber M. T. et al. (2009) *Space Sci. Rev., 150*, 63-80. [7] Kirk R. L. et al. (2008) *JGR,* 113, E00A24. [8] Jaumann et al. (2007) *PSS, 55,* 928-952. [9] Smith et al. (2001) *JGR,* 106, 23689-23722. [10] Barsukov V. L. ed. (1978) *Nauka Press,* Moscow, 183 p. (in Russian). [11] Basilevsky A.T. et al. (2014) *PSS, 92,* 77–87.

Table 1. The area occupied by slopes calculated on the bases 1, 1.5, 3, 5 m.

Slopes, degrees	Viking-1, 300x300 sq.m				MSL Curiosity, 300x300 sq.m			
	Area (%) calculated on the base							
	1 m	1.5 m	3 m	5 m	1 m	1.5 m	3 m	5 m
0-5°	81,13	82,64	88,90	94,15	71,19	75,37	85,75	91,28
5-10°	18,04	16,73	10,93	5,85	24,52	21,35	12,23	7,69
10-15°	0,79	0,60	0,17	0,00	3,72	2,92	1,98	1,03
15-20°	0,04	0,03	0,00	0,00	0,54	0,36	0,04	0,00
20-25°	0,00	0,00	0,00	0,00	0,04	0,01	0,00	0,00
>25°	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0
	Spirit, 300x300 sq.m				Lunokhod-1, 2000x4300 sq.m			
0-5°	80,38	83,34	90,52	94,73	59,86	69,35	73,96	78,40
5-10°	17,26	14,85	8,90	5,08	30,71	22,65	18,86	15,26
10-15°	2,03	1,59	0,52	0,19	6,22	5,12	4,60	4,06
15-20°	0,30	0,21	0,06	0,00	2,50	2,28	2,08	1,89
20-25°	0,03	0,01	0,00	0,00	0,66	0,57	0,47	0,38
>25°	0,01	0,00	0,00	0,00	0,06	0,05	0,03	0,01

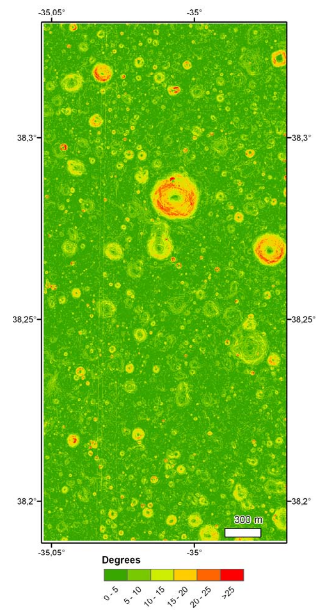

Fig. 5. Lunokhod-1 region. The slope map, base 1 m. (LROC NAC DTM) [NASA/GSFC/ASU] [4].

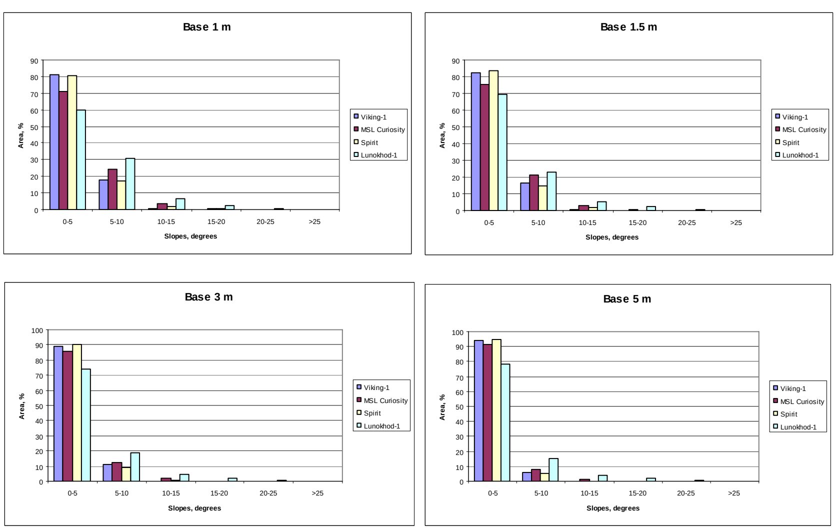

Fig. 1. The area occupied by slopes calculated for the bases 1, 1.5, 3, and 5 m.