LANDING SITE ANALYSIS FOR LOW-BUDGET LUNAR MISSONS – LANDING SITE CANDIDATES OF TEAM PULI SPACE, PARTICIPANT OF THE GOOGLE LUNAR X PRIZE. M. Deák[1] [1]Puli Space Technologies Ltd, Hungary, Budapest, 1162. Lajos utca 4. (marton.deak@pulispace.com); Department of Physical Geography, Institute of Geography and Earth Sciences, Eötvös Loránd University, Hungary, Budapest 1117. Pázmány Péter sétány 1/a (dmarton@elte.hu)

Introduction: Today, the most uncertain task of planning a surface lunar mission is to choose the landing site. Many aspects need to be considered and it is hard to find the balance between the possibility of mission success and a safe landing. It is possible to test most of the mission's (and the probe's) elements in a laboratory, while simulation of the landing site is still difficult, even by using the most advanced image and data analyzing processes.

The most important difference between low- and high-budget missions is the list of avalible technologies. In low-budget missions the engineering opportunities, for example the methodology of the descent and landing is restricted to cheaper and riskier solutions that lower the number of the accessible landing sites. Moreover, because of the lower budget, the safety factor by landing sites becomes even more important. Team Puli Space, contestant of the Google Lunar X Prize (GLXP) is to face such concerns as their mission is soon to be carried out.

Low-budget lunar probes: In a mission, the rover is built directly for the tasks ahead. So it is in Team Puli's case, as the Puli probe will be a simple rover that is able to complete the primary mission requirements set by GLXP: landing on the Moon, roving 500 meters, and broadcasting a live video feed to Earth (*Fig. 1*). These rovers are mainly ephemeral, small, light and not so complex compared to the ones used for government-funded missions.

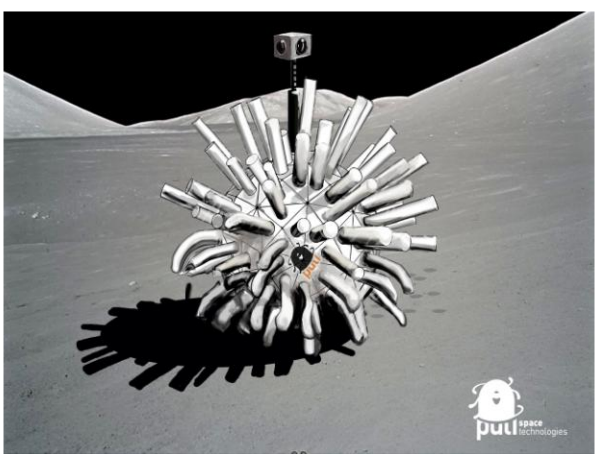

Figure 1: One of Team Puli's rover concepts

Methodology of choosing: As Team Puli's currently planned landing method has a 50 km inaccuracy, only those regions are considered that bear with the same characteristics in a wide area. Final choice was made considering 4 different aspects.

1) For a lunar landing site safety can be described by surface morphology, especially the crater density and the flatness of the wider area. These features can be determined using high-resolution LROC images. They can be used together with middle-resolution data, for example Clementine's UV/Vis images or LIDAR DEM's. Crater density is the largest threat for a surface mission, because even by relatively young mare areas crater coverage around 30% is very common. A cheap and small rover - what is used in low-budget missions - is unable to "climb out" from deep depressions.

In the process we used LROC images as samples and supposed, that if the whole area has the same mezo-morphology (determined by Clementine's UV/Vis and LIDAR), it has the same micro-morphology as well. In the end we used those areas only where the 5 meter (or bigger) diameter crater coverage was 15% at most. (*Fig. 2*).

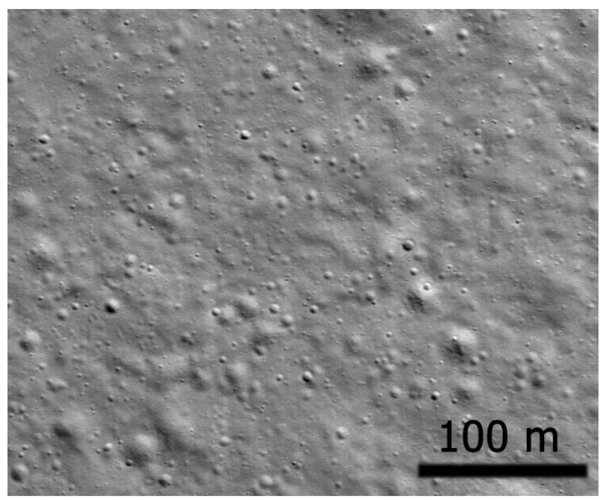

Figure 2: Sample area of one of Team Puli's landing site candidates, the Plato

2) The GLXP competition has some extra goals. One of those is finding water ice on the Moon. Areas in the polar regions, especially deep craters are where water ice is easier to be found. It is, however, a serious engineering challenge to put a rover there, because an instrument in those areas will have communicational and energy supply difficulties [1].

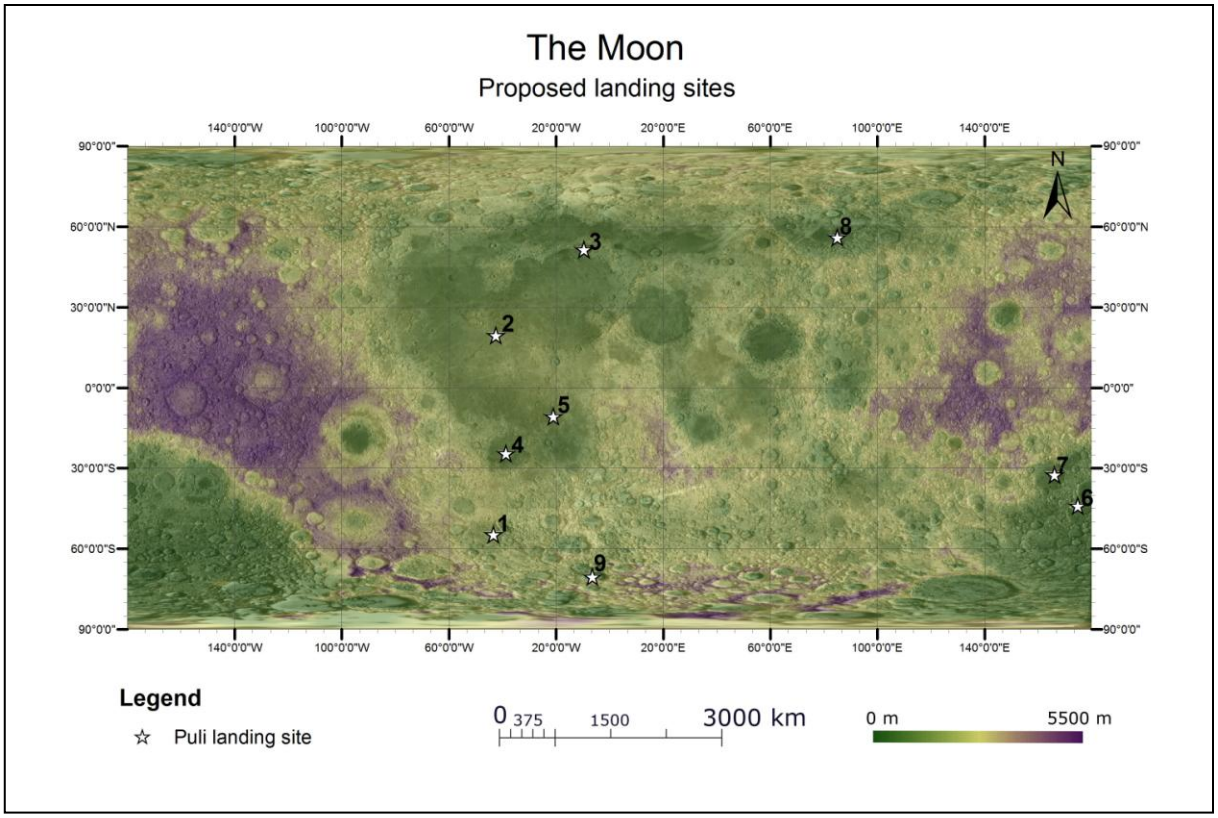

Figure 3: Te proposed landing sites of Team Puli

3) Education shall be important for a GLXP team, so landing sites named after someone famous are to be considered as landing sites too. One of those is for example the crater named after the Hungarian (just like Team Puli) scientist, Theodor von Karman.

4) Taking geological and physical measurements for investors can be done to raise the budget for the mission. One of these, for example, is the preparation of the imminent Helium-3 mining [2] by doing in situ measurements on the Moon, or maybe the analyzing of lunar lava tubes, which can be interesting for future human habitants [3].

The landing site candidates of Team Puli: Team Puli operates with 9 possible landing sites at this point (*Fig. 3*). We chose them by different aspects, but above them the possibility of a safe landing was always the most important.

Plato (3), Aristarchus (2), Mare Cognitum (5) and Mare Humorum (4) are young mare-areas with basaltic surface. The area next to Schiller Crater is very similar, but probably older (1). These regions have no special characteristics for the mission.

The Moretus Crater (9) is one of the deep polar craters. According to Clementine-LIDAR data, there are deep depressions, so it is possible that they contain water ice.

Thompson Crater (7), Von Karman Crater (6) and Mare Humboldtianum (8) are good targets too. Not only because of the educational opportunities given by their names, but they are on the far side of the Moon, so they may be richer in Helium-3.

Future work: Team Puli is only at the beginning, the exact location of the landing sites and the goals of the mission are still flexible. The methodology of the landing site analysis will remain the same.

Privately funded missions in the future will be able to reach only a restricted number of landing sites, so these missions will be smaller than the government-funded ones. Looking at the whole picture, these still restricted possibilities are huge steps for private teams, because in the near future not only government agencies, but private corporations will be able to explore the Moon.

References: [1] J. Ziglar et. al. (2007), Technologies toward Lunar Crater exploration, *Carnegie Mellon University – Robotics Institute* [2] In : S. A Stern – Worlds Beyond ; H. H. Schmitt (2002) *Return to the Moon!*, 76-84. [3] C. R. Coombs and B. R. Hawke (1992) In NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, *A search for intact lava tubes on the Moon: possible lunar base habitats*, 219-229