EXCAVATION OF PLANETARY REGOLITH IN NON-EASILY ACCESSIBLE PLACES USING WIRELINE TECHNOLOGY. K. Seweryn[1], [1]Space Research Centre PAS (CBK PAN), 18a Bartycka str., 00-716, Warsaw, Poland, kseweryn@cbk.waw.pl.

Introduction: ISRU (In Situ Resource Utilization) activities are becoming more popular among all key space agencies, and the international community is working towards one of two goals: a return to the Moon, or the exploration of small asteroids and comets. Both activities are designed to support the future exploration of Mars. Prospecting of bodies in space is the topic of several ongoing missions. For example, current developments related to the Moon's resources are presented in [1], while asteroids and comets come in many shapes and sizes – an overview is given in [2]. A specific example is the comet known as Churyumov Gerasimenko, which was discovered by European Space Agency's (ESA) Rosetta mission and its Phylae lander. The properties of this body are summarized in [3] and [4].

The breakdown of ISRU activities is provided in [5] where two important fields are related to resource prospecting and acquisition. Sampling and excavation devices are technical solution allowing to realize main function: to collect regolith but the difference between them is related to the scale of operation. Sampling systems acquire grams of regolith whereas excavation systems operates with kilos or tons. The Space Research Center (CBK PAN) at the Polish Academy of Sciences has developed two technologies related to sampling and excavation systems:

- a drill string based on a tubular boom; and
- a sampling device, called PACKMOON.

The proposal of excavation scenario as well as details of both technologies are presented in the followed sections.

Excavation scenario: The excavation scenario was prepared with assumption that the most valuable resources are in non-easily accessible paces on Moon such as Moon hole or Moon crater. Such places are difficult to access not only due to terrain morphology but also due to no light access during whole Moon day-night cycle. The proposed approach might be applicable to a water molecules (OH) rich regolith excavation. The scenario utilize the drilling wireline technology shown in [6] and is sketched on Fig 1.

In the proposed excavation scenario the deployment system is anchored on the crater edge. It is composed of two or more cylindrical spool with stowed tubular booms (2 booms per one spool). The prototype of similar system was also developed in CBK and presented in [7]. Once deployed the C shape tubular beams form a support structure for drill string actuated by specially designed actuator for tubular booms. It allows to move vertically the prospecting or excavation head. The prospecting head might be a drilling device (example in [8]) able to collect a core for further analysis. The excavation head might based on Packmoon sampling device [9] scale up to version able to collect hundreds of kilos of regolith. In proposed approach drill head not require orientation change so the drill string based on single tubular boom. The excavation head might require such option so the drill string is composed of 3 booms. Similar solution was proposed in [10].

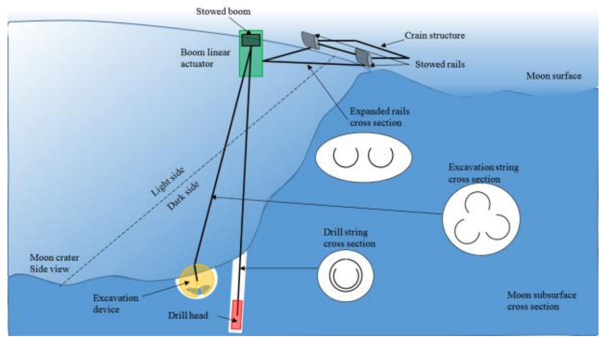

Fig 1. Excavation scenario of Moon crater with wireline technology.

Drill string: The Ultra-Light Mobile Drilling system (UMDS) was developed by the CBK PAN and AGH University of Science and Technology in Poland [8]. It is designed for drilling in extreme, particularly planetary, environments. Unlike conventional drill strings that are composed of several pipes that are screwed together, the UMDS uses tubular boom technology as a wireline system.

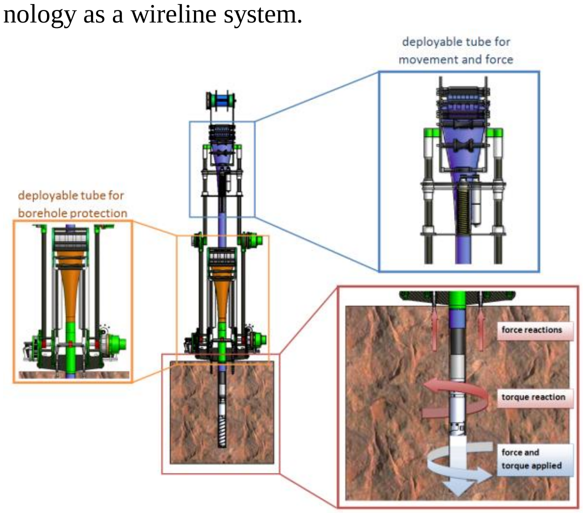

Fig. 2 UMDS schematic operation

This approach is much more efficient in terms of mass and volume and it is composed of three main components: a deployable tube (to protect the borehole), a deployable boom (to control drill head movements and apply force), and its dedicated actuator. These three components are shown on Fig. 2.

The drill string was tested with drill head on testbed system at AGH. The linear actuator proved ability to produce a force of over 400N, and could stabilize and guide the drill head during operations. The prototype of drill string, and drill head forced by linear actuator is shown on Fig. 3.

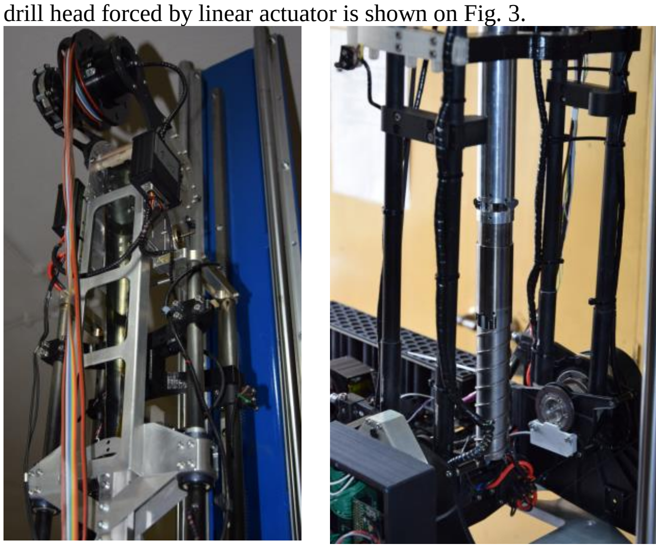

Fig. 3 Prototypes during tests on AGH in Krakow.

Sampling device: Drawing upon previous experience with Low Velocity Penetrometer (LVP) mechanisms [11], where the idea is to perform movements using a hammering action, a novel, rotary hammering principle was invented [9]. Unlike previous LVP devices that hammer themselves into the soil via linear movements, PACKMOON's spherical jaws are driven by a rotary movement [9]. The hammer's energy and momentum are transferred to the jaws in consecutive strokes. It accelerates against supporting masses and, since the system is kinematically symmetrical, the direction of movement of the hammer and the jaw oppose each other. Similarly, reaction torques from the hammer's acceleration and the horizontal component of reaction forces are opposite and canceled. After a number of strokes, the jaws close and the sample is collected. As this technique is highly efficient, the device only needs a small amount of energy for sampling. Sample are preserved in a container that can be automatically dismounted and inserted into, for example, the Earth Reentry Capsule.

Final, functional model of the PACKMOON device was developed in 2017 and is presented on Fig. 5. It was tested on a dedicated test rig to measure the reaction generated by PACKMOON's interfaces. It was also tested on an air bearing table that included both a PACKMOON emulator and a lander mock-up. The main aim of the project was to study the interaction between the unanchored lander and sampling devices on zero gravity bodies.

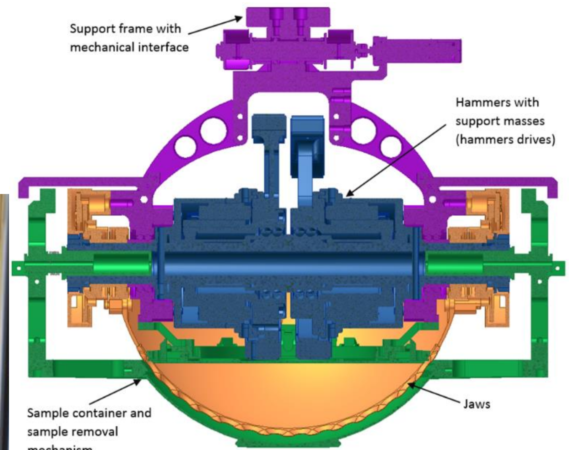

Fig. 4 PACKMOON prototype – cross section view).

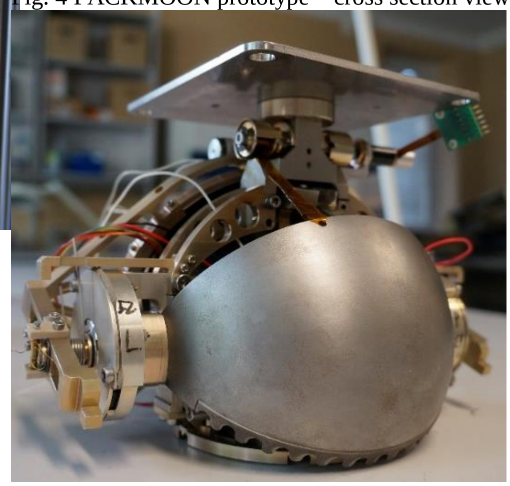

Fig. 5 PACKMOON prototype.

References:

[1] Crawford, I. A., (2015), *Progress in Physical Geography* 39(2), 137–167 (2015). [2] Michel, P., DeMeo, F. E., Bottke, W. F., (2015). *Asteroids IV*, University of Arizona Press, Tucson. [3] Spohn, T., et al., (2015), *Science*, 349 (6247). [4] Seweryn, K., et al., (2014) *Acta Astronautica* 99, 303–317. [5] D. L. Linne & G. D. Sanders, (2017), *PTMSS*, Montreal, Canada. [6] Zacny K., et al., (2013), *IEEE Aerospace Conference*, Big Sky, MT, USA. [7] Grygorczuk J., et al., (2013), *ASTRA conference*, Noordwijk. [8] Seweryn K., et al., (2014), *14th ASCE Earth and Space Conference*, St Luis Missouri, USA. [9] Seweryn K., (2016), *IEEE/ASME Transactions on Mechatronic systems* 21(5). [10] Kuciński T., et al., (2015) Chapter in Aerospace Robotics in GeoPlanet: Earth and Planetary Sciences, red. Jerzy Sasiadek; Springer.