Abstract for 11th Low Cost Planetary Missions Conference
June 9-11, 2015, Berlin, Germany

A Next Generation Heat Flow Probe for Planetary Missions

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Heat flow is a fundamental quantity characterizing the thermal state of a planet. Processes we observe at the surface like volcanism and tectonism are driven by heat released in the planetary interior through cooling and decay of radioactive elements, and surface planetary heat flow is the only observable directly related to a planet‘s interior heat. While heat flow was measured at more than 20 000 locations all over the Earth, technical difficulties and the limited availability of resources on planetary missions have prevented large scale exploration of heat flow on other planetary bodies. Thus, the only successful extra-terrestrial heat flow measurements to date have been performed during the Apollo 15 and 17 missions. This is going to change in the near future with NASA’s low cost InSight mission to Mars, which will deliver the Heat Flow and Physical Properties Package (HP3) to a landing site in Elysium Planitia. Amongst landing safety and other considerations the site was chosen to facilitate emplacement of the probe to a depth of up to 5m into low-cohesion regolith, which is assumed to be only moderately compacted due to wind being efficient in moving sand-sized particles on Mars.

To broaden the potential applications of the HP3 instrument to more demanding environments such as the Moon, which has a highly cohesive and strongly compacted regolith, the HP3 system could be easily improved by implementing propulsion developed in ESA funded PECS project EMOLE at the Space Research Centre of the Polish Academy of Sciences. The basic assumptions of propulsion and control electronics are the same as they were in MUPUS instrument (excluding stock arrangement and downscaling of coils) which was sent to comet 67P on-board Philae lander (Rosetta mission). Its principle of operation is typical for that kind of mechanisms (mole penetrators), where during energy exchange between three masses (hammer, counter mass, and outer casing), hammering action is performed. The main structural novelty – use of several electromagnets arranged in stock as a direct hammer propulsion – gave twofold improvements. First of all, owing to the fact that, in this case, the electromagnets do not need any drive transmissions and they do not have any rotating parts as in DC motor, the whole instrument became much simpler and more reliable. Secondly, the drive has ability to adjust hit energy during operation, which can save energy and protect the scientific instruments from damage. Furthermore, to provide an additional mode in which the typical operation is superimposed with a high frequency and low energy mode, a new electronics control module was developed. Noteworthy is that for the magnetic circuit a new material – Permendur 49 (instead of soft iron ARMCO B) was pre-tested and successfully implemented into the final design. During the upcoming months, concluding in April 2015, a full test campaign will be performed. Moreover, based on one-coil mechanism tests results, a maximum hit energy of a structure consisting of five coils, with 25.4 mm outer diameter, 254 mm of length and mass of ~800g, is predicted to be about 2.4J.