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Development of MINERVA-II2, a Micro-Robot for Asteroid Surface Exploration with Innovative Mobility

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This paper presents the development status of the MINERVA-II2 system equipped in the Hayabusa 2 spacecraft launched by JAXA. The MINERVA-II2 system consists of releasing covers and a micro-robot for asteroid exploration. The total weight of the system is just 1.6 kg, and is a lightweight system. The robot, named ROVER2, weights 877 g in total. It also has innovative mobility system as engineering challenges in addition to scientific missions such as acquisition of camera images and temperature sensors in a target asteroid. In the most challenging viewpoint, the MINERVA-II2 has been developed within limited resources; weight, power, size, time and cost. As a result, ROVER2 has designed to have tiny sized triple junction solar cells on the ROVER2 surface as power resources. Further to this, electric double-layer capacitors were employed as its power resource instead of batteries. The capacitors are available in wider temperature range than batteries. Owing to current enhancement of performance of the capacitor, commercial off-the-shelf (COTS) products enable a micro-robot to accomplish various exploration activities with lower cost. Additionally, ROVER2 has multiple actuators as its mobility. The first actuator is an eccentric motor, which consists of a brush-less DC motor. This actuator enables ROVER2 to micro-hop by the motor's vibration force. Moreover, elastic cilia mechanism on the ROVER2 surface fosters micro-hopping capability, and thus this is expected to achieve precise locomotion in a micro-gravity asteroid. The second actuator is a magnetic permanent magnet mechanism using a DC brush-less motor. This actuator consists of one movable magnet and two stationary magnets, and enables ROVER2 to hop by the impact force generated when the movable magnet sticks to the stationary magnet. This mechanism provides a large impact force in spite of low power consumption. The third actuator is a metallic and thin leaf spring. The actuator stores preliminarily the elastic energy of the spring by bending it. This enables ROVER2 to hop by the impact force generated when the bending energy releases. The stored bending energy is locked by "tegus" before its driving, and will be released all at once by burning off the tegus. ROVER2 has two metallic springs. Each spring is non-reusable but is highly reliable in harsh space environment because of its simple mechanism. The forth actuator is a shape memory alloy (SMA). The most advantage of this actuator is that it can work with a change of surrounding temperature. This enables ROVER2 to hop by the impact force generated when the SMA bends in a specific temperature condition. As for safety launch-lock, this is also locked by tegus so as not to drive in an unexpected situation. Unlike the third actuator using leaf springs, this actuator will be able to work semi-permanently with temperature shift. ROVER2 finally employs two different SMA mechanisms so that ROVER2 can move in different temperature ranges. Of particular note that the total weight of these four different types of actuators is just 88.1 g. The simplified system design of MINERVA-II2 enables to result in low cost missions.