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Future prospect of planetary exploration by penetrator technology

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A hard landing probe "penetrator" has been thought to be a very useful tool for the constitution of network stations on the planetary surface and subsurface, because it provides light-weight and cost-effective capabilities of deploying scientific instruments. A long-lived network science by penetrators gives unique possibilities for monitoring the global scale phenomena and for studies requiring simultaneous measurements (seismic, geodetic, magnetic, and meteorological observations) from several sites in one mission. In addition, utilization of penetrators for planetary explorations has some advantages over soft landing probes. The penetrator will make it possible to deliver scientific instruments into the planetary subsurface for in situ chemical analysis and/or heat-flow measurements; otherwise those measurements would require drilling holes from the surface. In situ geochemical measurements with higher resolution can also provide ground truth of remotely sensed data. For the reasons cited above, several planetary missions to use penetrator system have been proposed for a long time and developed by several space agencies. However, the actual space flight has not yet to be fulfilled, except for the European Rosetta spacecraft which has a penetrometry experiment and now under cruising.

ISAS/JAXA of Japan had planned to undertake a lunar mission named as LUNAR-A. The main objective of former LUNAR-A mission was to explore the lunar interior using seismometry and heat-flow measurements. The LUNAR-A penetrator mission had aimed to be the first demonstration to implement the geophysical network. To apply the penetrator system for planetary explorations, the most significant technical issue is an achievement of the shock-durability of the onboard instruments. Therefore, we need the understanding of dynamical aspect at the high-speed impact process into geological materials. And also, a sophisticated potting procedure is required under the severe limitation of weight and power supply.

On the other hand, the present design and manufacturing process of lunar penetrator which we developed for the former project have some disadvantages. One is the prolongation of potting procedure and only a few test trials. The second is the difficulty in partial repairs of payload instruments and their refurbishment. In addition, we have found difficulty to simulate the actual flight condition on the ground test facilities. In these years, we have been studying promising measures to improve the redundancy and robustness as well as multiple uses of penetrator system. Some of them were investigated in the laboratory environmental tests and others were fired for the verification of shock-durability in the high-speed impact tests.

In this study, we will report the application of penetrator technology to the future space program, and propose some mission configuration with the associated model payloads for the achievement of essential scientific objectives.