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Technical readiness of lunar penetrator and its application to future lunar exploration

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The scientific objective of the former LUNAR-A penetrator mission was to explore the lunar interior by seismic and heat-flow experiments. Two penetrators containing two-component seismometer and heat-flow probes would be deployed from a spacecraft onto the lunar surface, one on the nearside and the other on the farside of the moon. The data obtained by the penetrators would be transmitted to the ground station by way of the LUNAR-A mother spacecraft orbiting at an altitude of about 200 km. The seismic observations could be expected to provide key data on the size of the lunar core, as well as data on the deep mantle structure. The heat flow measurements at two different sites would also provide important data on the thermal structure and bulk concentrations of heat-generating elements in the Moon. The developed lunar penetrator is a missile-shaped instrument carrier and is about 75 cm in length, 14 cm in maximum diameter and about 14 kg in weight. The penetrator is of a cylindrical shape with an ogive-nose and it contains a two-component seismometer and a heat flow probe, together with electronics, primary batteries, a tiltmeter, an accelerometer, and radio communication system. To protect these onboard instruments from the impact shock, the inside of the penetrator case is potted by a mixture of high rigid epoxy-resin and glass micro-spheres.

The LUNAR-A mission was supposed to be launched in 2004, but it was postponed because there was not only a malfunction of subsystem of the orbiting spacecraft uncovered during testing but also technological problems occurred during the course of the qualification of the penetrator. The orbiter-related issues resulted in a replacement of the valves used in the Reaction Control System (RCS) of the spacecraft, following a recall issued by the manufacturer who found a malfunction of similar valves, and the latter is a fault found in the qualification level test of the penetrator in November 2003. During this impact test, we could not communicate with the penetrator at the proper timing, which was programmed before shot. On the other hand, the internal review board of ISAS/JAXA for launch readiness was made in 2004 and the review board recommended that the improvement of the communication link between the penetrator and the orbiting spacecraft should be made, based on lessons learned from the US Deep Space-2 and European Beagle-2 failure of their communication link. And then, the LUNAR-A project had been reviewed by both the internal and external review boards of JAXA from the viewpoint of technological assessment and project management. From recommendations of the review boards, we determined to focus our attention on the improvement of the penetrator system, following a suspension of development of the orbiting spacecraft. Finally, it was announced that the LUNAR-A mission was officially cancelled in February, 2007. The main reason is that the reliability would be questioned because of no more than two penetrators available, compared to the present JAXA's confidence level. Another reason of the cancellation lies in the deterioration in the quality of the instruments onboard the mother spacecraft due to the long-term storage since it has been manufactured. A revial program to solve the penetrator technology issues was initiated in 2005 for the validation of a high degree of redundancy and robustness, and then, four times impact load tests with low-temperature thermal stress were conducted using both mock-up and fully-integrated models. Finally, the program has been completed in 2010. The follow-on mission to utilize the penetrator technology is now under consideration for the future program of the Japanese lunar exploration and/or within the framework of international collaborations.