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Present status of SELENE-2 Lunar BroadBand Seismometer

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SELENE-2 is the first lunar landing mission of JAPAN. We have proposed a broadband seismometer system as a powerful candidate for a payload instrument. In this presentation, we present necessity of broadband seismometer observation and its scientific targets based on the results from the great observation of Apollo's passive seismic experiment.
The Apollo projects in 1970's made an equilateral triangle seismic station network at apexes of which Apollo 12, 14, 15 and 16 landed, with a side of about 1,000 km. The observation lasted over 7 years until September 1977 and it provided us information on seismic activities in the moon and internal structure to a depth of 1,000 km of the moon. It, however, had two weak points: (1) the size of the network is limited within 1,000 km and (2) sensitivity of the seismometers with a limited narrow band of 0.17 Hz is marginal to detect small deep moonquakes mostly often occurred. In addition, strong scattering of seismic waves made accuracy in the reading of P and S wave arrivals worse; typical errors are about 10 sec. Because of these reasons, accuracy in the structure model is also somewhat worse for deeper part of the moon than 200 km.
The SELENE-2 project plan to have only one landing site and we cannot run a seismic network observation in the project alone. Thus, we will try to derive more information from feeble seismic waveforms using a broadband (0.02-50 Hz) seismometer with 10 times sensitivity of the Apollo seismometers to overcome the point (2) above. A simulation for seismic coda suggests that we need a very slow seismic layer such as mega-legolith layer in which seismic energy is effectively trapped to reproduce long living scattering coda. The characteristic frequency of the shallow layer is about 0.12 Hz for the seismic velocity model of Nakamura (1981). We, therefore, expect clear detection of waves reflected and converted at an internal discontinuity such as core-mantle boundary if we get long period wave components more than 10 sec. The long period seismic waveforms provide us not only information on a location of an internal discontinuity but also that on a seismic velocity gap at the boundary. Long period seismology will definitely open a new frontier of lunar sciences. On the other hand, we will determine corner frequency of a deep moonquake. Although it was pointed that corner frequencies of deep moonquakes are much longer than those of earthquakes, the result is not conclusive because of the narrow band of Apollo's seismometers. Corner frequencies of deep moonquakes are important since they provide us information on the physical state in the region where deep moonquakes occur.
To realize a broadband and highly sensitive seismic observation on the moon as soon as possible, we make use of the heritage of a short period seismometer (SP) developed in the past Lunar-A project and a long period broadband seismometer VBB (LP) developed in the ExoMars project. We customize these seismometers to work properly under the severe condition of the lunar surface. We have also developed a survival module which relax strong temperature variations

with an amplitude of about 280 K for the seismometers to live long. It can control temperature of the sensors in a range of -10 to +30 degC. Advantage points of SP are light weight, shockproof and high generation of electricity (high sensitivity). Yamada et al. (2009) shows the Brownian noises are the primal noises of the sensor. We plan to reduce the noise level to a fraction of the level in the Lunar-A project. As for LP, we plan to reduce the noise level to a tenth of Apollo's LP in a frequency range of 0.1 to 1 Hz by growing capacitance of DCS and minimizing noises in the feedback circuit. VBB has a compensation mechanism for effect of temperature variations to work normally under the 40 degC temperature variation. We will verify the designed functions using proto models of the sensors and develop unimplemented functions.

Keywords: moonquake, broadband seismometer, lunar internal structure, core radius, crustal thickness, deep moonquake