OBSERVATION OF INFRASONIC/ACOUSTIC/SEISMIC WAVES INDUCED BY HYPERSONIC REENTRY OF HAYABUSA. M.-Y. Yamamoto[1], Y. Ishihara[2], Y. Hiramatsu[3], M. Furumoto[4], and K. Fujita[5], [1]Kochi University of Technology (185, Miyanokuchi, Tosayamada, Kami, Kochi 782-8502, JAPAN, yamamoto.masa-yuki@kochi-tech.ac.jp), [2]National Astronomical Observatory of Japan, [3]Kanazawa University, [4]Nagoya University, [5]Japan Aeronoutical Exploration Agency.

Introduction: In order to investigate vertical propagation process of the shock wave in the Earth's atmosphere, a hypersonic reentry of HAYABUSA spacecraft and its capsule was used as an artificial meteor event. Acoustic/infrasonic waves are important as one of the candidates of vertical energy transporter between the upper atmosphere and the ground. Most recently, on March 11, 2011, the great earthquake of East Japan and induced tsunami waves generates sonic waves in atmosphere, resulting radial gravity waves on the F-region ionosphere confirmed by the GPS-TEC plasma density perturbation over Japan [1].

Observation: Multiple-sites optical observation was carried out at ground observation sites (GOS) in Woomera Prohibited Area (WPA), Australia in June, 2010, by the HAYABUSA capsule resumption team of JAXA and related institutes. Since hypersonic reentry of artificial materials directly from the interplanetary space is extremely rare opportunity for testing vertical propagation of the shock waves, we deployed 5 infrasound sensors (Chaparral Physics Model-2 and Model-2.5) and 20 seismometers (Hakusan, SG820) in WPA. Three sites were used as arrayed seismic and infrasound stations. Optical observation of precise trajectory of the HAYABUSA reentry was also carried out at 4 GOS sites [2].

Results: The reentry of HAYABUSA capsule and mother spacecraft was clearly observed at the all ground sites at 13:51 UT on June 13. In the previous experiments in the Genesis and Stardust cases reentered over Utah, U.S.A., infrasound measurements were also carried out, being well explained by "weak shock" model [3] of explaining the overpressure wave generation by hypersonic entries of the natural meteoroids [4];[5]. The recorded signals at the three sites of 1.3, 1.0, and 0.7 Pa showed about 60% lower than the model calculation at the maximum of N-type shock waves, respectively.

Discussion: From the multiple-sites optical observation, the fragmentation process of the mother spacecraft was investigated in detail, where we checked 136 fragmented objects and its dissipation, being classified into three types: melting type, explosive type, and re-fragmented type. Investigating the coupling process between the overpressure shock waves and induced seismic waves is one of the purposes of our experiments. We deployed the both infrasonic/seismic sensors with a sampling rate of 100/125 Hz, respectively, at the same positions and coupling parameters were precisely measured at three sites, indicating flat relay functions in a frequency range between 0.1 Hz and 50 Hz. Direction finding of the incoming shock waves was carried out at a central site by using an arrayed infrasonic sensors, resulting good correspondence to the nearest point on the trajectory at about 40.6 km altitude. The main shock wave shows an impulsive spectrum not only in infrasonic region but also in audible zone up to 1 kHz, generating confirmable sound by human ear at the site. Moreover, after receiving the main shock generated by the reentry capsule, several successive sonic/infrasonic signals were recorded within 10 s. These signals were confirmed as the shock waves generated by several collapsed parts of the mother spacecraft, namely, there were one-to-one correspondences between the recorded signals and optically recorded illuminating parts clearly seen in the video frames [6].

Summary: During the hypersonic reentry of the Japanese spacecraft HAYABUSA on June 13, 2010, we observed the ablated process of the capsule surface as well as the fragmentation process of the mother spacecraft by optically and shock waves generated by these objects were clearly detected by the multiple-sites arrayed infrasonic/seismic sensors in WPA, Australia, indicating 60% correspondence to the current weak shock model for the hypersonic meteorite falls. Vertical propagation process of the overpressure waves in atmosphere was confirmed from the altitude over 40 km to the ground in acoustic/infrasonic range as well as the coupling function between the infrasonic waves and seismic waves was investigated in detail.

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Acknowledgement: The authors are grateful to Disaster Prevention Research Institute, Kyoto University, HAYABUSA capsule resumption team of JAXA. A part of this study is supported by the Ministry of Education, Sports, Culture. Science and Technology, Grant-in-Aid for Scientific Research (KAKENHI) (B), Field Research in Abroad, 22403005, 2010 (PI: Y. H.).