# DUST MONITORING INSTRUMENT ON CUBESAT FOR SMALL BODY MISSION.

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**Introduction:** NEAR Shoemaker and HAYABUSA landed on asteroids and Philae of Rosetta mission and HAYABUSA-2 are going to land on Churyumov-Gerasimenko comet and 1999 JU3 asteroid, respectively, as of writing this abstract. For such missions in the future, we suggest dust monitoring instrument on a CubeSat dispatched to the target body from the main spacecraft. CubeSat is a type of miniaturized satellite for space research and launching pod system is reliable. Using such small probe, we are able to investigate obviously-dangerous field where the main spacecraft does not approach. In this paper, we describe a concept idea of dust monitoring by CubeSat probe in small body mission.

**Purpose of dust monitoring:**

*Environment survey.* Dust particles may exist on the surfaces of or around bodies, asteroids and comets. Those dusts could affect spacecraft approaching the bodies for landing. Those dust can be risk on the spacecraft operation. For more security, the risk that the spacecraft would be damaged by dust impact, adhesion, and other effect has to be assessed and preliminary environment survey has to be conducted before approaching to the target body. The spacecraft must have navigation cameras and observe the surrounding space of the target bodies from remote position. But it is difficult to recognize small dust particles as mm to cm size from distant position unless the spatial density of the dust is sufficiently thick so that scattered sunlight can be detected.

*Impact ejecta monitoring.* In Hayabusa-2 mission, an impactor of 2 kg will be ignited to aim at the surface on 1999JU3 at 2 km/s. The imapct experiment will excavate the subsurface materials to be sampled. In such impact experiment, detecting ejecta grains will give us meaningful information on the surface and the interior of asteroids [1]. Recording the position and the time when ejecta grains are detected with DM, we reconstruct the trajectories of the grains and obtain their ejection speed and angle. In particular, the ejection angle is informative since the ejection angle reflects the porosity around the impact site: The ejection angle tends to become high for fluffy target [2]. In addition, the trajectory reconstruction enables us to determine the speed of the ejecta at the moment of detection. Assuming that DM detects the momentum of colliding grains, the grain mass (or size) turns out with the colliding speed determined.

**CubeSat:** The standard 10×10×10 cm$^3$ basic CubeSat is often called a “1U” CubeSat meaning one unit, and has a mass of no more than 1.33 kilograms. CubeSat has been a popular tool for engineers to test new technologies in space and often used for Earth remote-sensing, too. On the other hand, use of CubeSat for astronomical and planetary sciences has been rare because of severe constraints on payload. Since the first set of CubeSats was launched, enormous number of CubeSat were launched and a lot of knowledge are accumulated over years. One of advantages to use CubeSat system is ejection system of the CubeSat pod which is very reliable. Besides, if the probe for a small body mission is developed in CubeSat standard, a prototype of the probe can be demonstrated in the earth orbit because there are many opportunities for CubeSat launching.

As of the first lauch of CubeSat in 2003, the size is just a cube of 10×10×10 cm$^3$ and now the configuration of CubeSat is scaling up to 6U or 12U and is becoming more functional equipping with reaction wheels, thrusters for propulsion, deployable solar panels and so on.

For such small satellites as CubeSat, dust monitors has to be compact and low power consumption. We assume here that the CubeSat probe has a mission module part occupies a volume of 1 – 1.5 U.

**Instruments for dust monitoring:**

*Direct measurement method.* When the probe CubeSat is approaching to the target small body, environmental dust velocity relative to the probe is small. Sensors for dust monitoring around small bodies should have sensitivity to low speed impact. The low speed (< 1m/s) dust grains are not able to produce ionized plasma for detection of impact ionization as used for hypervelocity dust. Momentum sensor utilizes momentum transfer during collision between the grains and the detector. SESAME-DIM of Rosetta/Philae uses a momentum sensor of piezoelectric PZT for detection media and the target velocity range is 0.025 – 0.25 m/s [3]. The merit of this type of detector is its mechanical simplicity, compactness, and light weight, e.g. about 500 g for the detector system unit of MDM to be onboard BepiColombo having 64 cm$^2$ (four plates of 40 mm$^2$ sensor) of detection area [4]. Including sensor frame, a sensor unit consisting of four PZTs has a 10×10 cm$^2$ in area and three sensor units may be placed at the mission module part, directing to +X, +Y and +Z, respectively. Momentum sensor has sensitivity to acoustic vibration, so is likely to pick up a vibration from, for example, reaction wheel rolling, thruster blasting, and particle induced vibration propagating from the other area than the sensors as background. Those background noise can be rejected by simple signal analysis [5] and dust impact signal can be reduced down to a data rate as small as HK data, depending on what information is needed for dust environment and how much data rate is allowed to be sent back to the main spacecraft.

With more resources, dust monitoring instrument includes Time-of-flight (TOF) consisting of several layers of mesh grid in front of the PZT sensors. TOF sensor utilizes electrostatic induction while a charged particle passes through an electrode. The grain size can be inferred from the charge signal assuming the charge state of the incident particle is proportion to the size.

*Indirect measurement method.* After ejection, the CubeSat probe autonomously navigates with a few m/s approaching the target. If there are some debris like cm to 10 cm size or larger, they may have critical impact on the CubeSat probe when hit. For indirect measurement of dust in remote location, LIDAR (LIght Detection And Ranging) are useful. For dust observation, LIDAR was equipped with Mars lander Phoenix [6] and it conducted atmospheric measurement up to 15 km in altitude using Nd:YAG Laser with a pulse energy of 0.7 mJ. Lidar is powerful tool to survey distant region but pulse laser in space needs some resources and too much to put into CubeSat. In our study, survey region may be close as 100 m or less from the CubeSat probe, so we suggest to use the other type of semiconductor light source which is low luminescence and low power consumption.

**References:** [1] Kobayashi M. et al., *EPSC-DPS Joint Meeting 2011*, Abstracts, Vol. 6, EPSC-DPS2011-1847. [2] Schultz, P. H. et al. (2005) *Space Sci. Rev.*117, 207. [3] Seidensticker, K. J. et al. (2007) *Space Sci. Rev.* 128, 301. [4] Nogami et al. (2010) *PSS*, 108-115. [5] Kobayashi M. et al. (2014) *LPS XXXXV*, Abstract #2027. [6] Whiteway et al. (2008) *JGR*, 113, E00A08.