Development of the sprite and lightning imaging system onboard the SPRITE-SAT

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Sprites are large transient optical phenomena in the middle atmosphere associated with lightning discharges in thunderstorm. Lightning discharges are also suggested to produce gamma-ray radiation from the Earth, called terrestrial gamma ray flashes (TGFs). Concurrent measurements of lightning discharges and TGFs from space are important to understand the relationship between these phenomena. Nadia observations from spacecraft can provide information on the horizontal structures and distributions of sprites. These observations are, therefore, essential for understanding of the generation mechanisms of sprites and TGFs.

The SPRITE-SAT, a micro-satellite designed to investigate the generation mechanisms of sprites and TGFs, has been developed in-house by the Tohoku University team, aiming to launch it in August 2008. The total weight of the satellite would be less than 50 kg, including 4-5 kg science mission payload. This micro-satellite project has two primary science objectives. The first is to identify the generation mechanisms of sprites by investigating their horizontal structures. The second is to identify the generation mechanisms of TGFs by investigating their source location and relationship to lightning discharges.

The purpose of this research is to design and to develope the sprite and lightning imaging system composed of three cameras onboard the SPRITE-SAT and the establishment of the sprites and lightning remote-sensing measurements from space.

Lightning and Sprite Imager-1 and 2 (LSI-1 and 2) are CMOS cameras with 512 x 512 pixels and the pixel size of 25 um, which pointed at nadir to take images of the horizontal structures of lightning and sprites. In order to detect lightning emissions, we equip LSI-1 with a broad band filter between 740 and 830 nm because intense lightning emission lines are in this near infrared range. We also equip LSI-2 with a rather narrow band-pass filter centered at 762 nm which enable us to eliminate the light emission from lightning flash, occurring in deeper atmosphere, because the wavelength range around 762 nm includes one of the most intense emission bands of sprites and the oxygen absorption bands. The optics and the detector array altogether yield an effective field of view (FOV) of 35 deg, giving the pixel resolution of less than 660 m from the altitude of 660 km. The power consumption is 0.47 W. Wide Field CCD imager (WFC) is a CCD camera with 659 x 494 pixels and the pixel size of 7.4 um, which takes images of lightning discharges inducing TGFs. WFC is also pointed at nadir and is equipped fish-eye lens (FOV is larger than180 deg). The power consumption is 1 W. The outputs of all cameras are digitized by 10 bit A/D conversion. One instrumental case contains LSIs and WFC and the total weights is 630 g.

Science instruments are controlled by the Science Handling Unit (SHU) which includes a FPGA (Field Programmable Gate Array) and a DSP (Digital Signal Processor). Input/output ports and image processing algorithms are developed with the FPGA and the DSP, respectively. The FPGA-based trigger logic for saving image data only for lightning flashes or sprites has been developed using the Bread Board Model (BBM). The GPS time counting logic has been also developed with the FPGA logic. Verification of the trigger logic with the PC lightning simulator confirms that the trigger logic can detect transient emissions with high accuracy.