SENSITIVITY CHANGE ANALYSIS OF OPTICAL NAVIGATION CAMERA (ONC) FOR HAYABUSA2 EXTENDED MISSION. M. Yamada[1], T. Kouyama[2], K. Yumoto[3], E. Tatsumi[4], T. Morota[3], N. Sakatani[5], M. Hayakawa[6], M. Matsuoka[6], R. Honda[7], C. Honda[8], S. Kameda[5], H. Suzuki[9], K. Ogawa[6], K. Shirai[10], H. Sawada[6] and S. Sugita[3], [1]Chiba Inst. Tech. (manabu@perc.it-chiba.ac.jp), [2]AIST, [3]Univ. of Tokyo, [4]IAC, [5]Rikkyo Univ., [6]JAXA, [7]Kochi Univ., [8]Aizu Univ., [9]Meiji Univ., [10]Kobe Univ.

Introduction: After completing observations and sample collection on asteroid Ryugu from June 2018 to November 2019, Hayabusa2 successfully delivered the acquired samples from Ryugu to Earth during the Earth swing-by on December 6, 2020. Currently, the Hayabusa2 team is planning a flyby of the asteroid 2001 CC_{21} in July 2026 and a rendezvous to the asteroid 1998 KY_{26} in July 2031 as an extended mission.

The Optical Navigation Camera (ONC) onboard Hayabusa2 is a two-dimensional CCD camera system consisting of three camera heads: a multi-wavelength spectroscopic telephoto camera (ONC-T) and two monochrome wide-angle cameras (ONC-W1, W2) [1-4], and will be used to observe the shape and surface condition of the target asteroid during the extended mission. On the other hand, it has been reported that the optical performance of the ONC has degraded due to the adhesion of surface materials flown up during the two touchdowns to the Ryugu surface [5], leading to a concern that the optical performance may further degrade in the upcoming 10 years. In order to plan the observation sequence by clarifying the constraint of the exposure time when observing new target asteroids, we estimate the sensitivity change using the calibration observation data using the FF lamps onboard ONC-T, which has been conducted since after the launch.

FF lamp calibration: The FF lamp is mounted in front of the optical system of the ONC-T and allows almost constant light to enter the photosensitive area of CCD sensor even in deep space. By comparing the imaging data with this lamp turned on, we can estimate the sensitivity change of the entire CCD. Figure 1 shows the v-band FF lamp image acquired on December, 2014, just after launch. Because the two lamps are installed diagonally, there are two areas brighter than the other field of view. The lamp voltage can be set to High or Low, which are used for short wavelengths (ul, b, v, and Na bands) and long wavelengths (w, x, p, and wide bands), respectively. When set to Low, the brightness of the lamp depends on the temperature of the ONC-AE rather sensitively. Thus, it is necessary to correct for this dependence [4].

Figure 2 shows the sensitivity change history of the ONC-T using the FF lamp images acquired from launch to July 2021. The value on the vertical axis is the average of the count values in all pixels of the CCD divided by the value immediately after launch. After about a year of launch, there was a large drop in the ul band to ~5%. Subsequently, however, the change was less than 2% at most in all bands until arrival at Ryugu in June 2018. After the first touchdown in February 2019, there was a 4-5% drop, and after the second touchdown in July 2019, there was a 6-7% drop in all bands. It also tends to decrease at lower wavelengths. After the departure from Ryugu, there is no significant decrease, and there was apparent small increase.

Figure 1. FF ramp image taken with ONC-T v-band in December 2014.

Predicted sensitivity change and exposure time for extended mission

Assuming that the gradual sensitivity change rate of ~2%/1302 days from launch to arrival at Ryugu will continue and that a rapid sensitivity loss of 12% due to touchdowns do not occur after departure from Ryugu, the sensitivity degradation at the time of approach to asteroids 2001 CC_{21} and 1998 KY_{26} are estimated to be 16.5% and 19.3% compared to the condition immediately after launch, respectively (Table 1). Considering that the range of albedo of the target asteroids is between 4% and 20%, and that the heliocentric distance of the asteroids are between 1.21 and 1.67 x 10^8 km, we estimated the exposure time ratio compared to the exposure time in Ryugu as shown in Table 1. Qualitatively, because 2001 CC_{21} is closer to the Sun than Ryugu, it should have a shorter exposure time. In contrast, 1998 KY_{26} has a larger distance from the Sun, it should have a longer exposure time. In the Wide band, the exposure time used for Ryugu imaging was only two steps higher than the minimum configurable setting. Thus, the signal might be saturated in cases where the albedo of 2001 CC_{21} is high.

Conclusions: The sensitivity change of the ONC-T during the observation of the new target asteroid in the extended mission of Hayabusa2 was estimated. From the point of view of keeping within the configurable exposure time range, ONC-T is expected to be able to image without any problems in the seven major bands used for scientific observations except for the wide band.

Acknowledgments: This study was supported by JSPS Core-to-Core program International Network of Planetary Sciences.

References: [1] Kameda, S. et al. (2015) *Adv. Sp. Res., 56, 1519.* [2] Kameda, S. et al. (2017) *Space Sci. Rev., 208, 17.* [3] Suzuki, H. et al. (2018) *Icarus, 300, 341*. [4] Tatsumi, E. et al. (2019) *Icarus, 325, 153*. [5] Kouyama, T. et al. (2021) *Icarus, 360, 114353*.

Table 1. Estimated sensitivity loss rates and exposure time ratio at the new target asteroids.

Asteroid	Ryugu	2001 CC_{21}		1998 KY_{26}	
Spectral types	C	L		L	
Arrival date	2018/06/27	2026/07/15		2031/07/15	
Days since arrival at Ryugu	0	2940		4766	
Estimated Sensitivity Loss[%]	---	16.5		19.3	
Heliocentric **distance [km]**	1.4665E+08	1.2062E+08		1.6710E+08	
Albedo [%]	4	20	4	20	4
Exposure time ratio	1	0.16	0.81	0.32	1.61

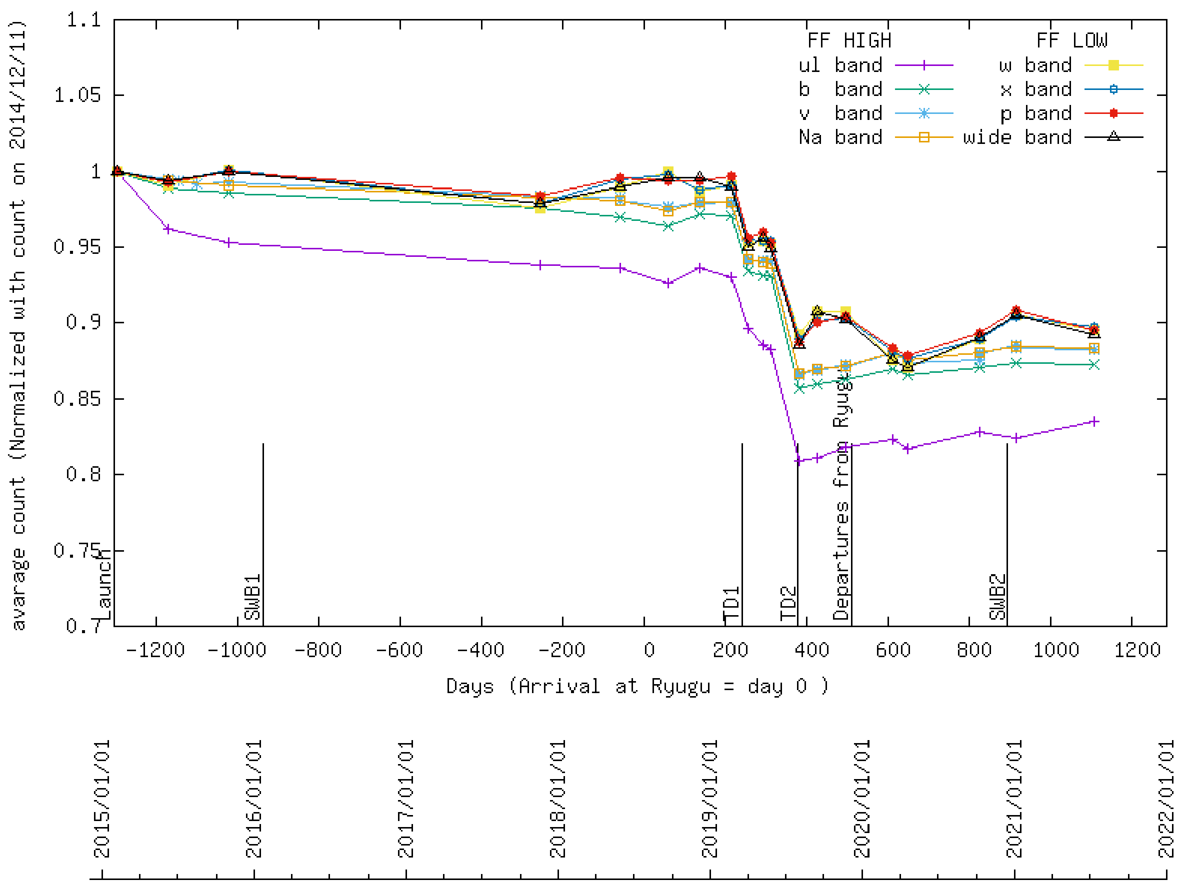

Figure 2. ONC-T sensitivity change history from spacecraft launch to July 2021.