TELESCOPIC CAMERA (TENGOO) AND WIDE-ANGLE MULTIBAND CAMERA (OROCHI) ONBOARD MARTIAN MOONS EXPLORATION (MMX) SPACECRAFT. S. Kameda[1] (kameda@rikkyo.ac.jp), H. Kato[1], N. Osada[1], M. Ozaki[2], K. Enya[2], T. Kouyama[3], H. Suzuki[4], H. Miyamoto[5], and A. Yamazaki[2] ,[1]Rikkyo University, [2]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (ISAS/JAXA), [3]National Institute of Advanced Industrial Science and Technology, [4]Meiji University, [5]The University of Tokyo

Introduction: JAXA's Martian Moons Exploration (MMX) is planned to be a sample return mission from Phobos, one of the satellites of Mars. The nominal instruments have been selected and two of them are Telescopic Nadir imager for Geomorphology (TENGOO), Optical Radiometer composed of chromatic imagers (OROCHI), near infrared spectral imager (MacrOmega), gamma-ray and neutron spectrometer (MEGANE), ion mass spectrometer (MSA), dust monitor (CMDM), and LIDAR.

One of the scientific objectives of MMX is to determine the origin of the two martian moons. Phobos and Deimos seem to be asteroids captured by Mars' gravity according to the result of spectroscopic observation of the surface reflectance. Conversely, they also seem to have been formed by a large impact of a body with Mars and subsequent accretion [1]. Elemental analysis is necessary to clarify the origin of the moons.

The MMX mission will acquire more than 10 g of regolith on the surface of the moon. A coring unit will be installed with a core diameter of 10–20 mm. Assuming that the sample is representative of Phobos, we will be able to clarify the origin of the moons. To test this assumption, we should determine suitable landing sites and identify the uniformity or nonuniformity of the distribution of surface material. Though we can obtain the globally averaged elemental composition using the GNS, the distribution of the elemental composition cannot be obtained by the selected instruments with a resolution of ~10 mm. Additionally, we should select the landing site where the flatness is <~30 cm in the range of 5 m in diameter. In this paper, we show the conceptual design of TENGOO and OROCHI and the requirement will be satisfied by these two instruments.

Instrumentation: TENGOO is composed of a Ritchey-Chretien telescope and CCD image sensor. In the conceptual design, the instantaneous field of view (iFoV) is 6 micro-radian/pix and Modulation Transfer Function (MTF) of optics is 0.3 at Nyquist frequency. Thus, the spatial resolution is 13 cm (2 pixels) at the altitude of 11 km in the quasi satellite orbit, in which we should select the landing site. The iFoV is 16 times higher than that of Optical Navigation Camera (ONC) onboard the *Hayabusa2* spacecraft (100 micro-radian/pix) [2]. Signal to Noise ratio is > 30 with an exposure time of 10 ms. Figure 1 shows the conceptual optical design. The diameter of the main mirror is 120 mm and the focal length is 950 mm. Figure 2 shows its MTF. Note that this conceptual design would be modified after the selection of prime contractor of this instrument.

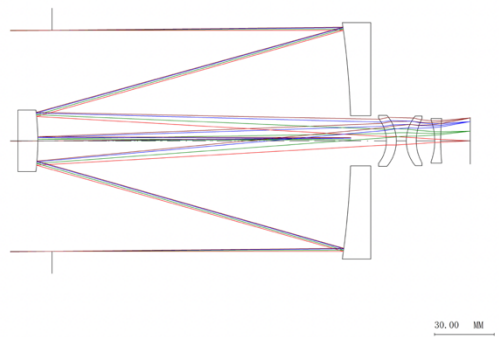

Figure 1: Optical design of TENGOO.

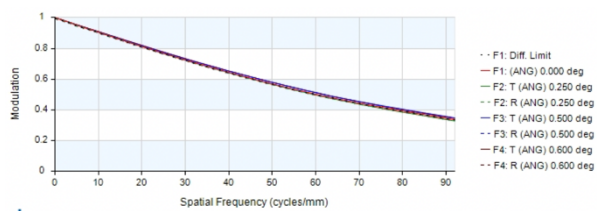

Figure 2: MTF of optics for TENGOO

OROCHI is composed of 7 wide-angle bandpass imagers and 1 panchromatic imager. Figure 3 shows conceptual design of OROCHI. We decided not to use a filter wheel which is used in *Hayabusa2* and OSIRIS-REx missions. Because of the high ground speed (~10 m/s) in descending and ascending phases, if it takes several seconds to change the filter, the field of view (FoV) of images with the 7 bandpass filters would not overlap. In OROCHI, we could take 7-color images simultaneously and get fully overlapped images.

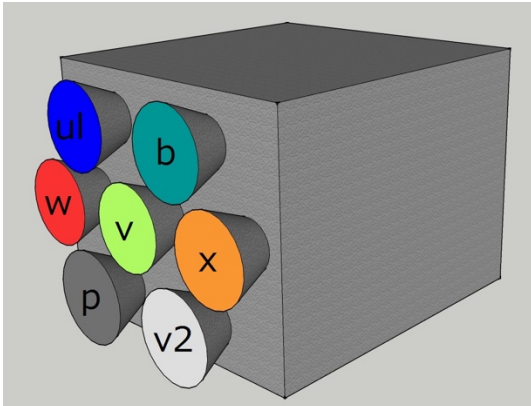

Figure 3: Design of OROCHI

The wavelengths are 390 nm, 480 nm, 550 nm, 650 nm, 700 nm, 800 nm, and 950 nm. The FoV is > 1 radian and the iFoV is 0.4 milli-radian and the MTF of optics is 0.3 at Nyquist frequency. Figure 4 and 5 show the optical design of optics for OROCHI and its MTF.

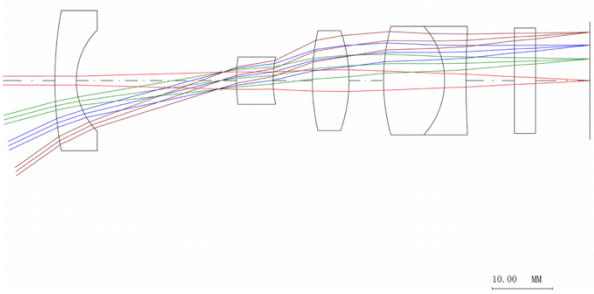

Figure 4 : Optical design of OROCHI

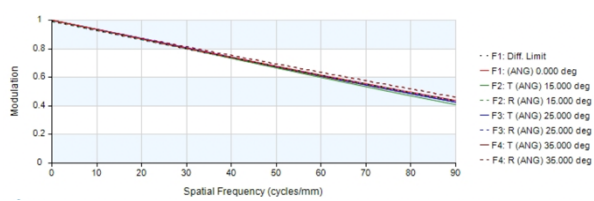

Figure 5: MTF of optics of OROCHI

Additionally, we have one panchromatic imager dedicated for imaging at landing phase. The object distance, the distance between the instrument and Phobos surface, is estimated to be 0.5 to 1 m. The spatial resolution would be ~3 mm using the 7-color imagers dedicated for remote sensing, however, the typical particle size is estimated to be ~1 mm at the surface of Phobos and the spatial resolution of 1 mm is required to clarify the surface condition. The design of the panchromatic imager is quite similar to the others except that it has no filter and the sensor position is a little bit shifted to focus a close object. Figure 6 shows the relationship between spatial resolutions and observation altitudes for cameras onboard MMX, OSIRIS-REx, and *Hayabusa2* for comparison.

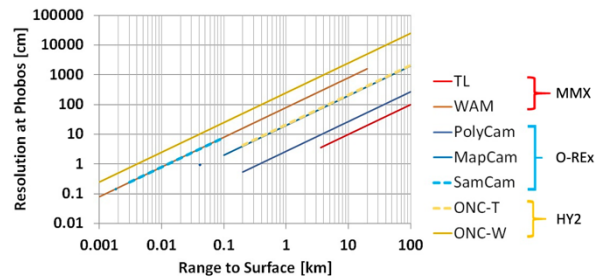

Figure 3: Spatial resolutions of cameras onboard MMX, OSIRIS-REx, and *Hayabusa2*

Summary: JAXA's Martian Moons Exploration (MMX) mission is to reveal the origin of Phobos and Deimos. Both of the moons are to be observed by remote sensing and sample return from Phobos will be done. The nominal instruments have been selected and two of them are Telescopic Nadir imager for Geo-morphology (TENGOO) and Optical Radiometer composed of Chromatic Imagers (OROCHI). The scientific objective of TENGOO is to obtain the geo-morphological features of Phobos and Deimos. Spatial resolution of TENGOO is 13 cm at the altitude of 11 km in the quasi satellite orbit, which is 16 times higher than that of the telescopic camera onboard *Hayabusa2*. The scientific objective of OROCHI is to obtain material distribution by spectral mapping. OROCHI is composed of seven wide-angle bandpass imagers without a filter wheel and one panchromatic imager dedicated for landing phase. Using these two instruments, we plan to select landing sites and get information supportive for analysis of return samples.

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References: [1] Rosenblatt et al. (2016) Nat. Geosci., 9, 581–583. [2] Kameda et al. (2017) Space Sci. Rev. 208, 17-31.