METEOR OBSERVATION HDTV CAMERA ONBOARD THE INTERNATIONAL SPACE STATION.

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Introduction: Meteor showers occur when the Earth's orbit crosses meteoroid streams which are mainly derived from comets. When a comet approaches to the Sun in its orbit, meteoroids spread out along the orbit of the comet due to vaporization of ice, resulting in a meteoroid stream. Also, it has been recently shown that short-period meteor showers are not generated from the water vapor drag of active comets, but rather the result of infrequent disintegrations of comet-asteroid transition bodies [e.g. 1-3]. Such examples are the Geminids and Quadrantids, which originated from a breakup of asteroids 3200 Phaethon and 2003 EH1, respectively. Major meteor showers annually occur in the known specific timeframe. Possible parent bodies which are dynamically linked with the major meteor showers are identified (Table 1). Since the velocity of the meteoroids of each meteor shower is known (Table 1), the size of the meteoroid can be estimated based on its flight path and light curve. Chemical composition of the meteoroid can be determined by the emission spectra. Thus, observation of meteor showers is important in understanding the physical and chemical propertoes of not only meteoroids, but their parent comets or asteroids. These studies are also critical in planetary defence, because some meteor-parent asteroids, i.e. 3200 Phaethon are potentially harzardous asteroids, which have risk of meteor impacts on Earth. To date, most meteor observations have been performed on the ground. They are weather dependent and limited to a narrow observation range. The International Space Station (ISS) is an ideal platform for continuous meteor observation without distortion caused by weather and atmospheric disturbances.

Table. 1. Major meteor showers as observation targets

Meteor shower	Active window (peak day)	Velocity	ZHR*	Parent body
Quadrantids	01/01-01/05 (1/3)	41km/s	120	Asteroid 2003 EH1, Comet 1490Y1
April Lyrids	04/16-04/25 (4/22)	49km/s	18	Comet Thatcher
η-Aquarids	04/19-05/28 (5/5)	66km/s	60	Comet1P/Halley
Southern δ-Aquarids	07/12-08/19 (7/28)	41km/s	20	Comet1P/Halley
Perseids	07/17-08/24 (8/12)	59km/s	100	Comet 109P/Swift-Tuttle
October Draconids	10/06-10/10 (10/8)	20km/s	var	Comet 21P/Giacobini-Zinner
Orionids	10/02-11/07 (10/21)	66km/s	23	Comet 1P/Halley
Southern Taurids	09/25-11/25 (11/5)	27km/s	5	Asteroid 2004TG10
Northern Taurids	09/25-11/25 (11/12)	29km/s	5	Comet 2P/Encke
Leonids	11/10-11/23 (11/17)	71km/s	var	Comet 55P/Tempel-Tuttle
Geminids	12/07-12/17 (12/14)	35km/s	120	Asteroid 3200Phaethon
Ursids	12/17-12/26 (12/22)	33km/s	10	Comet 8P/Tuttle

*Zenithal Hourly Rate (ZHR): The number of meteors a single observer would see in one hour under a clear, dark sky if the radiant of the shower were at the zenith. Var: variable

Fig. 1. Photo of (a) the HbCMOS HDTV camera attached with a lens and a wide-angle converter, (b) WORF rack in Destiny (Photo courtesy NASA). Observation is done through the window.

Mission overview: We will fly a Meteor observation system (Chitech Observatory of METor on iSS: COMETSS) with a super sensitive color high definifition TV (HDTV) camera (Fig. 1a, Table 2) and a lens (F 0.94, f=17.5mm, FOV 46 deg) to the pressurized US Lab module (Destiny) of the ISS, install it on the Window Observational Research Facility (WORF) rack (Fig. 1b), and will conduct a continuous meteor observation through the window (Fig. 1b) in Earth's orbit for two years. The reflective coating on the window absorbs UV radiation, but transmittance rises rapidly after 304 nm to > 90% in the visible and into the near infrared. The Meteor camera is equipped with IR cut filer, which provides visible light only, up to 700 nm. We will also install a transmitted diffraction grating in front of the lens for the spectral analyses of the meteoroids, to estimate meteors' elemental abundance. The atomic emission lines of major elements are located within the visible wavelength; Fe I (370nm), Ca I (393nm), Mg I (518nm), Na I (589nm). The flux data collected will allow better comparison of physical and chemical data among major meteor showers and their parent bodies.

Operation and System configuraion: The ISS orbits the Earth for 90 minutes at an altitude of 400 km with an orbital inclination of 51.6 deg. The ISS night time where the Sun is beneath the horizon viewed from

Table. 2. Specification of the COMETSS camera.

Image sensor	HbCMOS
Sensor size	2/3 type (9.6mm × 5.4mm)
Valid pixels	1280(H) × 720(V)
Pixel pitch	7.5 micron
Frame frequency	30 fps
Mount	Micro Four Thirds
Mass	0.8 kg
Dimension (mm)	82 × 82 × 140
Power consumption	15 W
FOV only with a lens	28.4 deg (H) × 16.4 deg (V)
FOV with a lens & wide-angle converter	38.8 deg (H) × 22.8 deg (V)

the ISS is about 35 minute in a single orbit. With the ISS orbiting the Earth sixteen times in one day, available night time for the meteor observation is about 560 minutes. The field of view (FOV) from the window is restricted due to other pressurized module, a robotic arms and docked launch vehicles (Fig. 2). Because of the relatively narrow FOV of the COMETSS (Table 2), the COMETSS will be installed normal to the window with a distance of 2-3 inches between the bumper ring attached to the lens and the window glass.

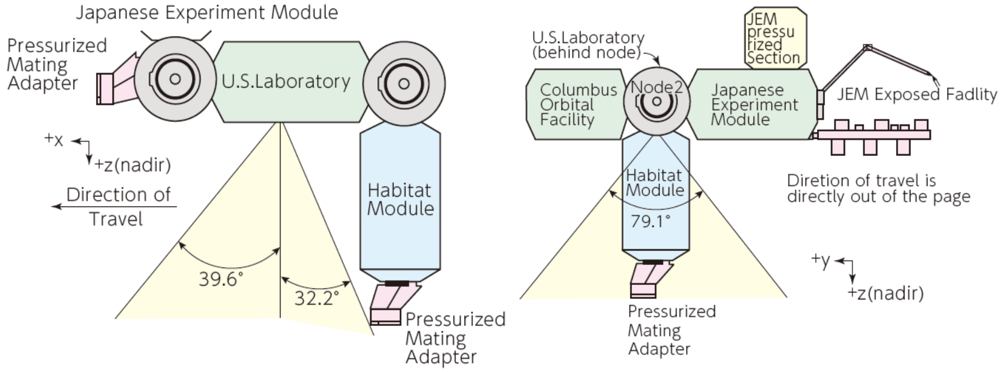

Fig. 2. Field of view from the WORF window.

The COMETSS system consists of a Hyper bit CMOS sensor (HbCMOS) HDTV camera, a lense, an encoder, a power distribution box and a laptop PC (Fig. 3). Except the focus adjustment which is supported by the ISS crew, all the operation of the COMETSS is remotely conducted on the ground. Operation plan files are uploaded to the onboard laptop PC. The onboard software on the PC perform on/off of the camera and the encoder, and processing/analyse of the observation data, on the basis of the operation plan.

The operation time of the WORF rack will be shared with other payloads, such as ISS SERVIR Environmental Research and Visualization (ISERV) and Sally Ride Earth Knowledge Acquired by Middle Schools (EarhKAM). With the shared operation timeframe, we propritize the observation targets: primary (periods around the peak of major meteor showers, secondary (periods outside of the peak of major meteor showers, minor meteor showers, and periods with little or no regular meteor activity identified), and tertinary as targest of opportunity (observation of de-orbiting spacecraft, and daytime terrestrial targets upon the request of NASA).

Data analyses & handling: Due to the constraint of the maximum downlinkable data volume of 200MB per day from the ISS, all the acquired data can not be downlinked. A software is being developed for autonomous detection of meteors in the acquired image data, and extraction of the data including meteor images, so that the image with meteors can only be downlinked and the downlinked data volume can be minimized. We may also lower the bit rate of the data to further decrease the downlikned data volume. The downlinked data will be analyzed for scientific interests, and will be openly distributed via internet for the purpose of education and public outreach.

Development status and future schedule: Both the hardware and software of the COMETSS are currently under development. Once the development and verification testing are completed in Japan, the COMETSS will be delivered to the U.S. for final testing and crew training prior to the launch, which is currently scheduled to be late 2014. In order to properly estimate physical properties from the luminosity of the meteoroid, and to correctly deduce elemental abundance from the visible spectra, we will conduct calibration tests, using light sources and stars.

References: [1] P. Jenniskens (2006). Meteor Showers and their Parent Comets. *Cambridge University Press*, Cambridge, U.K., 790 pp. [2] D. Jewitt & L. Jing (2010) *Astronomical Journal*, 140:1519–1527. [3] D. Jewitt et al. (2013) *Astrophysical Journal Letters*, 771:L36 (5pp), doi:10.1088/2041-8205/771/2/L36.

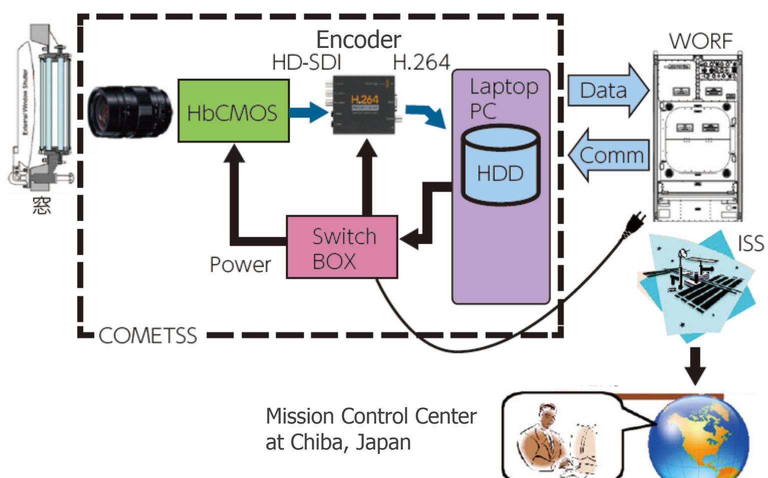

Fig. 3. Block diagram of the COMETSS system