INTERNATINOAL SPACE STATION-BASED METEOR OBSERVATION PROJECT: INITIAL RESULTS. T. Arai, M. Kobayashi, M. Yamada, H. Senshu, K. Wada, S. Ohno, K. Ishibashi, R. Ishimary, K. Maeda and T. Matsui, Planetary Exploration Research Center, Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino, Chiba 275-0016, Japan (tomoko.arai@it-chiba.ac.jp).

Introduction: Meteors are light phenomena resulting from the entry of dust particles (meteoroids) of millimeter to centimeter in size, into the Earth's atmosphere. Meteor showers occur when the Earth passes through stream of dusts which are derived from specific comets or asteroids. These small bodies dynamically linked with dust stream of meteor showers are called meteor parent bodies. Annual meteor showers occur during the same period every year. Major annual meteor showers and their parent bodies are listed in Table 1. As the velocity of meteoroids of each meteor shower is known (Table 1), the size of the meteoroid can be estimated based on its brightness and light curve. Chemical composition of the meteoroid can be determined by the emission spectra. Thus, optical observation of meteor showers is important in understanding physical and chemical properties of meteoroids and their parent bodies. The International Space Station (ISS) is an ideal platform for continuous meteor observation without distortion caused by weather and atmospheric disturbances.

Mission overview: We conduct two-year long meteor observation project (named METEOR) onboard ISS, using a super sensitive, color high definition TV (HDTV) camera (Fig. 1) equipped with a wide-angle, bright lens (F 0.95, f=10.5mm, diagonal FOV 57.8 deg). The camera is installed in front of window of the Window Observational Research Facility (WORF) of the pressurized US Lab module (Destiny). Antares rocket for the first launch and Falcon 9 rocket for the second both failed in October 2014 and June 2015. METEOR was succesffuly launched with Atlas V rocket on March 22, 2016 for the third time luck. The observation started on July 7th, 2016 and is currently underway (Fig.2).

Table 1. List of majot anual meteor showers

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	Comet 96P Machholz
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

Photometric observation is done in visible wavelength. 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. A transmitted blazed diffraction grating is installed in front of the lens for the spectral observation 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 the ISS is about 35 minute in a single orbit. With the ISS orbiting the Earth 16 times in a single day, total night time for tmeteor observation is about 560 minutes.

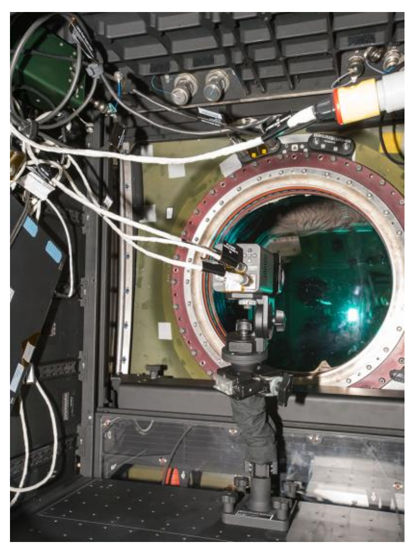

Fig. 1. Photo of METEOR camera (a) before launch (upper) and (b) installed on the WORF rack in Destiny after launch (right) (Photo courtesy NASA).

Except aperture adjustment and HDD swap which need crew support, all the operation of METEOR is remote ly conducted from the operation center resided in our institute. Recording schedule is uploaded to the onboard PC in advance of observation. The onboard software on the PC performs on/off of the camera and the encoder, and processing/analyse of the observation data, based on the uploaded batch files. The shutter for the window is open while no visiting vehicle is docked to Node2 Nadir. With a visiting vehicle docked on Node2, the shutter open time is limited for 5-6 hours per day, according to the flight rule.

Data analyses & handling: With allowable data downlink rate (max. 4 Mbps) and with available command window of 9 hours per day, maximum downlinkable data volume per day is 6-9 GB. A single night pass data of about 35 minutes with 20 Mbps is 5.5 GB. Thus, all the acquired data can not be downlinked. All the recorded data are stored in a 750 GB HDD installed in the onboard PC. 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 in future The downlinked data is used for scientific interests, and is openly distributed by internet for the purpose of education and public outreach.

Initial results and upcoming study: Table 2 summarizes meteors captured on July 30 during a peak of Southern Delta Aquarids meteor shower. Due to the high beta angle of ISS till July 28, observation could be done only on July 29-31. In order to estimate physical properties from luminosity of the meteoroid, we will determine the luminosity of each data based on the ground calibration test data, using light sources.

References: [1] T. Arai (2014). LPSC 45th abstract #1610. [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. 2. Composit image of first bright meteor captured on July 15, 2016. ISS robotic arm is in the FOV.

#	Observation time	Longitude	Latitude
2016/7/30			
pass 02	03:47:30 - 04:04:36		
1	3:50:46	-42.1553E	47.5327N
2	3:52:29	-33.9426E	44.5672N
3	3:53:08	-31.0748E	43.2845N
4	3:56:13	-19.1381E	36.2641N
5	3:56:21	-18.6779E	35.9316N
6	4:03:40	1.7782E	15.5316N
pass 03	05:20:03 - 05:37:31		
7	5:21:25	-75.8004E	49.9662N
8	5:23:06	-66.7680E	47.8555N
9	5:23:36	-64.2465E	47.0859N
10	5:25:38	-54.8028E	43.3817N
11	5:25:46	-54.2287E	43.1100N
12	5:26:11	-52.4692E	42.2408N
13	5:27:10	-48.5188E	40.0759N
14	5:28:21	-44.1172E	37.2843N
15	5:28:52	-42.3065E	36.0096N
16	5:31:26	-34.1708E	29.2730N
17	5:35:05	-24.4535E	18.8780N
18	5:36:45	-20.4952E	13.9335N
pass 04	06:52:37 - 07:10:25		
19	6:55:07	-93.0517E	48.6043N
20	6:56:16	-87.1799E	46.8941N
21	6:57:00	-83.6512E	45.6396N
22	6:58:57	-75.0871E	41.7724N
23	7:01:07	-66.8636E	36.7483N
24	7:03:56	-57.8320E	29.4037N
25	7:04:30	-56.1971E	27.8437N
26	7:04:54	-55.0740E	26.7290N
27	7:06:22	-51.1499E	22.5594N
28	7:06:52	-49.8738E	21.1122N
pass 05	08:25:10 - 08:43:18		
29	8:30:13	-104.1021E	44.3947N
30	8:30:40	-102.1153E	43.5075N
31	8:32:36	-94.26[illegible]	[illegible]
32	8:36:59	-79.90	
33	8:38:05	-76.859[illegible]	[illegible]
34	8:38:34	-75.5760E	23.5588N
35	8:40:16	-71.2816E	18.6200N
36	8:42:19	-66.4557E	12.5211N
pass 06	09:57:43 - 10:16:12		
37	10:07:10	-110.6587E	34.3462N
38	10:09:21	-103.9413E	28.5223N
39	10:12:13	-96.2772E	20.3710N
40	10:12:28	-95.6562E	19.6404N
41	10:12:49	-94.7972E	18.6132N
42	10:13:27	-93.2714E	16.7430N
43	10:15:39	-88.2012E	10.1545N
pass 08	13:02:50 - 13:21:57		
44	13:03:22	162.1657E	50.6678N
45	13:03:53	165.1186E	50.2227N
46	13:03:55	165.3071E	50.1912N
47	13:05:13	172.4351E	48.7120N
48	13:08:08	-173.4059E	43.8411N
49	13:09:18	-168.4825E	41.4062N
50	13:09:28	-167.8121E	41.0397N
pass 09	14:35:24 - 14:54:59		
51	14:39:17	156.6288E	46.4136N
52	14:39:52	159.3962E	45.3880N
53	14:40:55	164.1077E	43.3655N
54	14:41:13	165.3912E	42.7493N
55	14:42:20	169.9344E	40.3226N
56	14:42:59	172.4168E	38.8224N
57	14:43:16	173.4637E	38.1502N
58	14:43:39	174.8473E	37.2244N
59	14:46:28	-176.0064E	29.9330N
60	14:48:36	-170.0416E	23.9779N
61	14:49:24	-167.9672E	21.6757N
62	14:49:31	-167.6709E	21.3374N
63	14:49:50	-166.8743E	20.4160N
64	14:50:39	-164.8669E	18.0204N
65	14:50:42	-164.7461E	17.8729N
pass 10	16:07:58 - 16:27:41		
66	16:15:41	149.4674E	38.4585N
67	16:19:30	161.8979E	28.5999N
68	16:21:39	167.7534E	22.5314N
69	16:23:34	172.5030E	16.9250N
70	16:23:40	172.7413E	16.6286N
71	16:24:49	175.4273E	13.1986N
72	16:25:23	176.7187E	11.4957N
73	16:26:26	179.0678E	8.3232N
74	16:26:42	179.6569E	7.5146N
pass 11	17:40:31-18:00:33		
75	17:44:36	110.6655E	46.0275N
76	17:46:36	119.5699E	42.1360N
77	17:46:38	119.7079E	42.0649N
78	17:47:58	124.9680E	39.0774N
79	17:51:41	137.3204E	29.5938N
80	17:51:52	137.8574E	29.0925N
81	17:54:02	143.8113E	22.9997N
pass 12	19:13:05 - 19:33:24		
82	19:15:44	80.0994E	48.2589N
83	19:16:27	83.7516E	47.1864N
84	19:17:18	87.8751E	45.7563N
85	19:18:20	92.5808E	43.8096N
86	19:19:24	97.0929E	41.5894N
87	19:21:02	103.3699E	37.8415N
88	19:21:39	105.5582E	36.3335N
89	19:22:54	109.7228E	33.1459N
90	19:28:27	124.9616E	17.5421N
91	19:28:30	125.0818E	17.3943N
92	19:32:34	134.3140E	5.1604N
pass 14	22:18:13 - 22:39:05		
93	22:23:21	45.2087E	43.9581N
94	22:29:12	66.4006E	29.9231N
95	22:36:42	85.1686E	8.0714N
96	22:38:00	88.0167E	4.1204N