P02

たんぽぽ捕集パネルの微小粒子衝突痕分析の状況

Progress of Micrometeoroids and Micro Debris Crater Analysis on TANPOPO Capture Panels

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たんぽぽはISS曝露部の簡易曝露実験装置（ExHAM）を用いた宇宙実験の一つで，ISS高度の微生物捕集や，微生物の耐宇宙環境性評価等の，アストロバイオロジー実験が主な目的である．曝露されたパネルには微小粒子も多く衝突することが予想されるため，粒子衝突痕を使ったデブリ環境モデルの妥当性評価も，たんぽぽのサブミッションとして位置付けられている．たんぽぽ捕集パネルは，メッシュ状のアルミケースに超低密度エアロゲルが設置された構造をしている．パネルは1年間ExHAMで曝露された後，宇宙飛行士によって回収され，新しいパネルに交換される．最初のパネルは2015年5月に曝露を開始し，現在も実験は継続中である．本講演では，2016年と2017年に帰還した捕集パネルの分析状況について報告する．また，デブリ環境モデル（MASTER-2009）で予想される捕集パネルの衝突頻度について，デブリ衝突リスク解析ツールTURANDOTを使った解析を実施している．解析の状況についても報告する．

TANPOPO is an astrobiology experiment using the ExHAM (Exposed Experiment Handrail Attachment Mechanism) installed on the ISS Kibo Exposed Facility. Main missions of TANPOPO are collecting microbes on the ISS orbit, exposing radiation-resistant microbes, and so on. Many micro meteoroids and debris also impact on the TANPOPO panels. Therefore, a sub-mission of TANPOPO is validation of debris environment models by impact craters. TANPOPO capture panels are made of ultra low density aerogels put into meshed aluminum alloy cases. The panels are exposed on the ExHAM. After 1 year, astronauts collect them and install new panels. First experiments started from May 2015. This presentation shows analysis progress of panels returned to the earth in 2016 and 2017. The impact frequencies on the panels are estimating with MASTER-2009. The analysis progress by JAXA's debris impact risk analysis tool (TURANDOT) is also introduced in this report.

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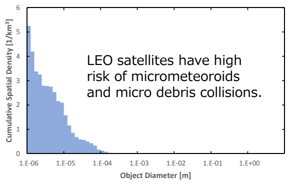
1. Introduction



Space debris impact on LEO satellites at 10 km/s in average.

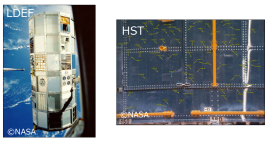
→ Even a micro particle impact can cause critical damage for LEO satellites.

Tracking individual orbit of each micro particle is impossible.

→ Impact risk for a satellite assesses with space debris environment models.

Debris environment model is developed based on on-orbit measurement data.

Measurement data used in MASTER-2009
- LDEF (NASA) 1984-1989
- EuReCa (ESA) 1992-1993
- HST (NASA/ESA) 1989-1993 etc.

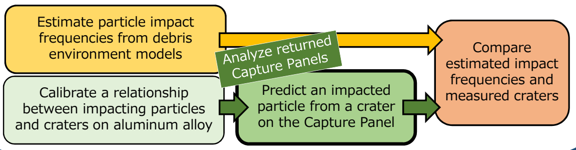


Continual on-orbit measurement of micro particles is important to ensure reliability of debris environment model.

Objective of this study
Validation of debris environment model by craters on TANPOPO capture panels

● TANPOPO Capture Panels
- An ultra low density aerogel in an aluminum alloy case
- Exposed area – Aerogel : Aluminum = 6:4
- Installed on 3 surfaces of ExHAM on ISS KIBO exposed facility
- An astronaut collects after 1 year exposure and install new panels
- First experiment started in May 2015

● Analysis Procedure

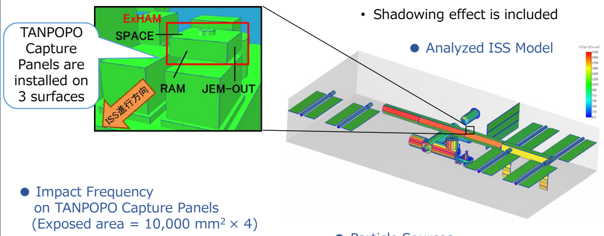


2. Impact Frequency Estimation [1]

Environment Model	MASTER-2009 (ESA)
Analysis Term	1 Jan 2015 - 31 Dec 2015
Altitude	400 km
Eccentricity	0
Inclination	51.6°

Particle impact frequency is analyzed with "**Turandot**"
- Debris impact risk assessment tool developed by JAXA & MUSCAT Space Engineering
- Impact frequency is analyzed by a spacecraft 3D model and a debris environment model
- Shadowing effect is included

● Analyzed ISS Model

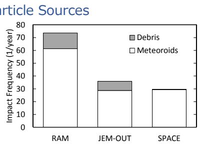


● Impact Frequency on TANPOPO Capture Panels (Exposed area = 10,000 mm² × 4)

Particle Diameter	Impact Frequency (1/year)		
	RAM	JEM-OUT	SPACE
100 μm ≤	0.18	0.10	0.08
10 μm ≤	14.7	6.03	7.48
1 μm ≤	73.6	35.9	33.2

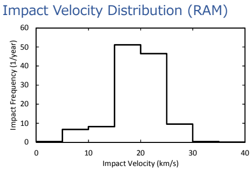
Particles smaller than 100 μm expect to impact on the Capture Panels

● Particle Sources



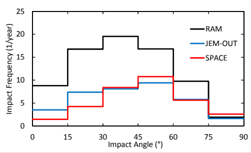
Most of impacting particles are meteoroids

● Impact Velocity Distribution (RAM)



Particles impact at 15-25 km/s on the RAM surface

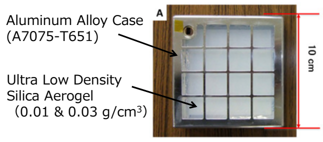
● Impact Angle Distributions



Most particles impact at oblique angle

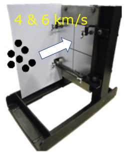
3. Analysis of Aluminum Parts [2]

● TANPOPO Capture Panel

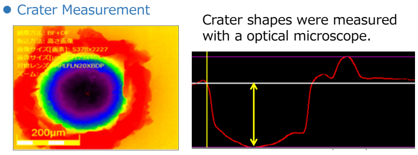


● Calibration Experiments on Ground

Projectile
Aluminum, Aluminum-oxide, Stainless steel
φ100 - 500 μm
Target
A7075-T651
t= 3 & 5 mm



● Crater Measurement

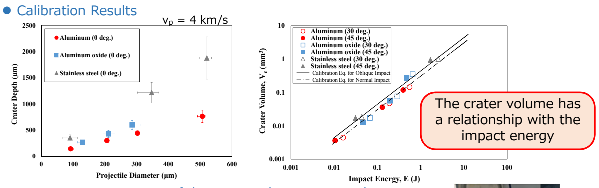


Crater shapes were measured with a optical microscope.

Crater depth was defined as distance between the surface and bottom of the crater.

Volume under the surface line was defined as a crater volume.

● Calibration Results

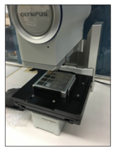


● Measurement Progress of the Returned Capture Panels

Totally 23 panels returned from space.

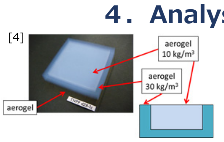
Crater measurement of the Al cases is ongoing.

Returned Year		2016	2017
Number of Returned Panels	SPACE	4	4
	RAM	3	4
	JEM-OUT	4	4



4. Analysis of Aerogel Parts [3]

[4]



Aerogel is transparent and colorless solid with silicon dioxide as a component.

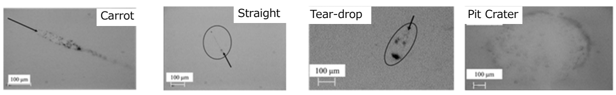
Due to it is low density, micrometeoroids and micro debris can be captured as blocks.

● Analyzed Tracks in the Aerogel Returned in 2016

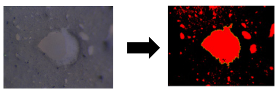
	Track Shape	Carrot	Straight	Tear-drop	Pit Crater
Number of Tracks L_c > 100 μm	SPACE (ExHAM1)	8	5	1	5
	SPACE (ExHAM2)	1	2	2	3
	RAM	12	4	31	4
	JEM-OUT	28	5	4	4

Tracks larger than 100 μm in characteristic diameter were analyzed.

The track shape vary depending on impact speed, impact angle, particle properties, etc.



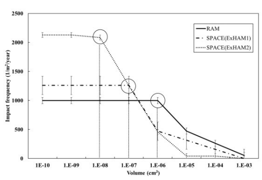
● Track Volume Measurement



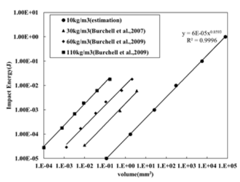
Track volume was measured from optical microscope images of the track.

The images were analyzed with ImageJ/Fiji.

● Flux Measured from Returned Aerogel



● Calibration



The relationship between the impact energy and the track volume was estimated from past studies.

References

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[2] 尾田佳至朗, 他, たんぽぽ捕集パネル衝突デブリ推定式における衝突角度の検討, 平成27年度宇宙科学に関する室内実験シンポジウム, 2016年.

[3] 山本啓太, 他, 国際宇宙ステーションでの超高速衝突粒子フラックス評価：たんぽぽ捕集パネルに対する遮蔽と衝突放出物の影響, 第62回宇宙科学技術連合講演会, 2018年.

[4] Tabata ,M., et al., Conceptual Design of a Silica-aerogel-based Cosmic Dust Collector for the Tanpopo Mission on Board the International Space Station, 29th International Symposium on Space Technology and Science, 2013.