Research on Radiation Protection Technology

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Abstract

In order to realize future human space mission while ensuring astronauts safety, space-radiation protection technologies are required. Our goal is to establish the accurate estimation technology of space-radiation exposure doses and the method to optimize shielding designs for spacecrafts.

Reasons for using JSS2

We use JSS2 for PHITS (Particle and Heavy Ion Transport code System) Monte Carlo simulations to estimate shielding effects of materials against space radiations. PHITS Monte Carlo simulations take a large amount of time when the computational system is large and complex, such as the system simulated manned-spaceship structure. Such simulations enable to be run at high speed with statistical accuracy by using JSS2.

Achievements of the Year

In order to establish exposure dose estimation technology based on numerical simulation using radiation transport code for future human missions, it is needed to evaluate the validity of existing radiation environment models and the appropriate setting of calculation geometry.

This time, we created the International Space Station (ISS) and Japan Experiment Module (JEM) 3D-CAD models and calculated the doses inside JEM using PHITS code. And, the calculated doses were compared with experimental doses obtained by Area PADLES (Passive Dosimeter for Lifescience Experiments in Space) dosimeters, and we examined the validity of the used environment models and the appropriate setting of the spacecraft geometry.

The ISS 3D-CAD model includes JEM, some modules close to JEM (e.g. Columbus, Node 1-3), and truss structures (Fig. 1a). JEM 3D-CAD model includes Pressurized Module (PM), Experiment Logistics Module Pressurized Section (ELM-PS), Exposed Facility (EF), and Node 2 (Fig. 1b). Inside PM and ELM-PS models, seventeen virtual PADLES dosimeters are installed at the same positions as actual ones. The files of such CAD models were converted to PHITS input format by SuperMC (Super Monte Carlo simulation program for nuclear and radiation process) software. Each part of ISS and JEM models was composed of Al alloy or Al.

As trapped proton (TP) and galactic cosmic ray (GCR) models, AP8 and Matthia model were used, respectively (Fig. 2). East-west effect of TP, which is a bias that the number of incident TP from the ISS moving direction (+X direction) is larger than that from backward direction (-X direction), is set as 0.5 (considered) or 0 (not considered). Absorbed dose (D) and dose equivalent (DE) in the virtual dosimeters were calculated using PHITS code by parallel computing (JSS2).

Fig. 3 and Fig. 4 show calculated and measured (experimental) doses and their ratios (C/E), respectively. As shown in Fig. 4, the calculated D and DE are in agreement with measured data mostly within ~20% and ~30%, respectively, regardless of the differences of used geometry and setting of east-west effect of TP. This result suggests that the dose estimation using the combination of AP8, Matthia model, PHITS, and the ISS / JEM model created this time has enough accuracy in terms of dose estimation. And, the mean C/E obtained by using the ISS model is almost the same as that obtained by using JEM model. Therefore, considering time efficiency in calculation, detail geometry is not necessarily, and it is important to use a geometry reproducing the surrounding shielding environment of the position where estimated an exposure dose for reasonable estimating. We plan to establish dose estimation method which is applicable in actual space missions by using the outcome of this work.

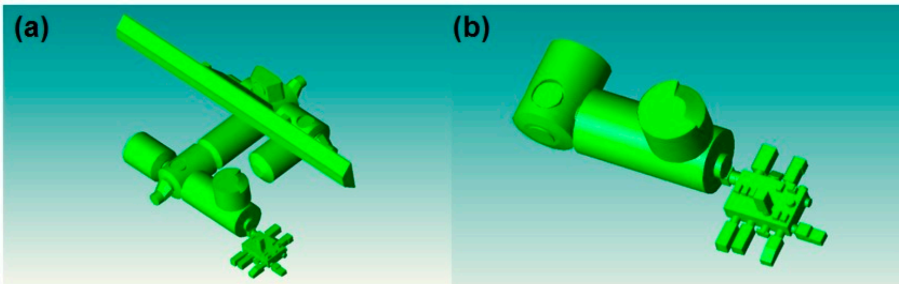

Fig. 1: (a) The ISS and (b) JEM 3D-CAD models

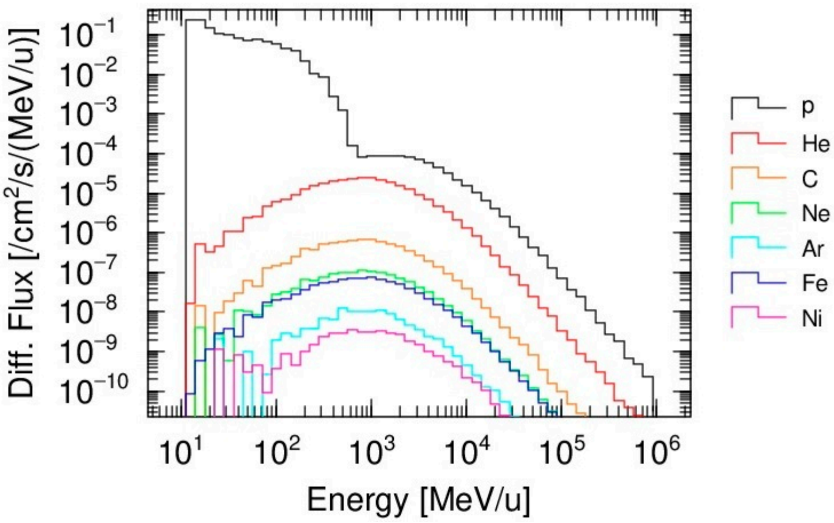

Fig. 2: Particle energy spectra obtained from Matthia model and AP8 model.
(period: Area PADLES #14 (Mar 28, 2015 - Sep 12, 2015) ; Only p (proton, H), He, C, Ne, Ar, Fe, and Ni spectra are shown.)

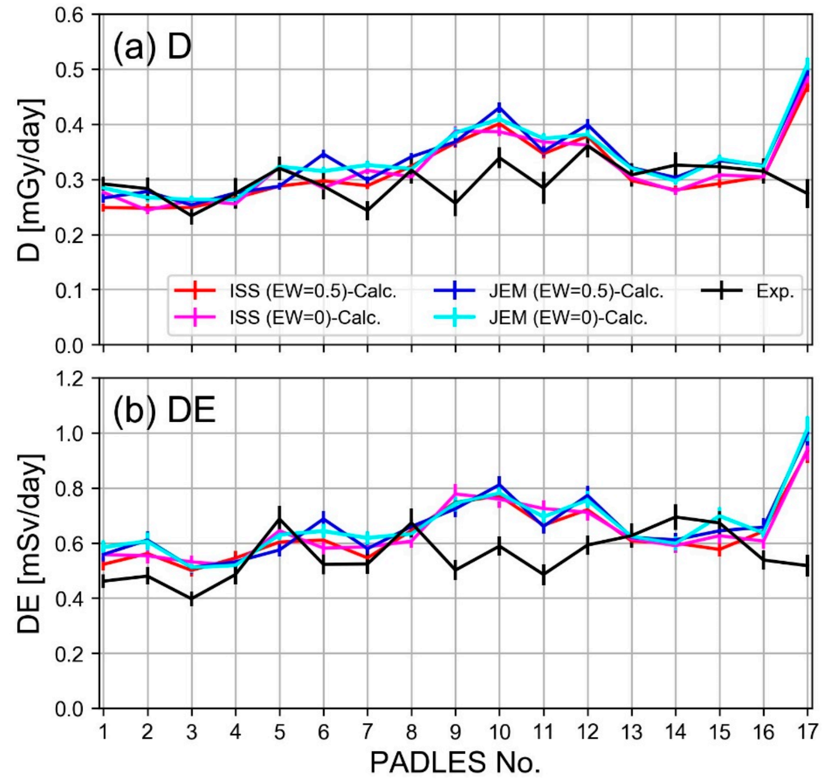

Fig. 3: Calculated and measured (a) D and (b) DE in the period of Area PADLES #14 (Mar 28, 2015 - Sep 12, 2015)

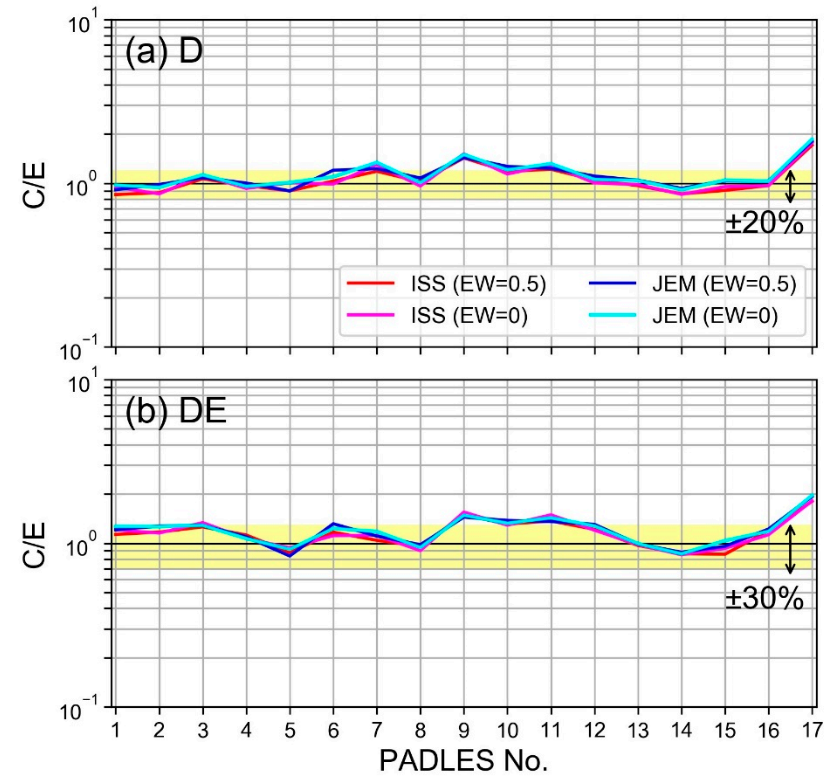

Fig. 4: Calculated and measured dose ((a) D and (b) DE) ratios (C/E) in the period of Area PADLES #14 (Mar 28, 2015 - Sep 12, 2015)

Publications

- Oral Presentations

1) Aki Goto, Kazunori Shimazaki, Tatsuhiko Sato, Exposure Dose Calculation inside JEM Using PHITS and 3D ISS Geometry, 42nd COSPAR Scientific Assembly, 2018.

2) Aki Goto, Kazunori Shimazaki, Tatsuhiko Sato, Dose Calculation inside Kibo Using PHITS and ISS 3D-CAD Geometry, WRMISS-23, 2018.

3) Aki Goto, Kazunori Shimazaki, Exposure Dose Estimation inside Kibo Using ISS 3D-CAD Model and PHITS, PHITS Workshop, 2018.

4) Aki Goto, Kazunori Shimazaki, Exposure Dose Estimation inside JEM Using ISS 3D-CAD Model and PHITS, 14th Space Environment Symposium, 2018.

Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	12 - 120
Elapsed Time per Case	60000 Second (s)

Resources Used

Fraction of Usage in Total Resources*1 (%): 0.54

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	0.00	0.00
SORA-PP	910,385.36	7.28
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	14.31	0.01
/data	4,978.18	0.09
/ltmp	2,929.69	0.25

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*2: Fraction of Usage: Percentage of usage relative to each resource used in one year.