Long-term orbital environment prediction by orbital debris evolutionary model

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Abstract

Increase of space debris is a problem for reliability of sustainable space activity. JAXA has researched space debris related technology for space debris mitigation and environmental remediation. The effectiveness of space debris countermeasures is evaluated based on the prediction of future orbital environment using the orbital debris evolutionary model (NEODEEM) jointly developed by JAXA and Kyushu University.

Ref. URL: http://www.kenkai.jaxa.jp/research/debris/debris.html

Reasons and benefits of using JAXA Supercomputer System

NEODEEM predicts the situation of over 200 years orbital propagations of more than 20000 elements and orbital events by using Monte-Carlo method (evaluate the average of 100 runs). Therefore, JSS3 is used to reduce run time and to process a large amount of data. TOKI-RURI is used for compatibility with PC version (Linux, WINDOWS).

Achievements of the Year

As a part of the evaluation of the future orbital environment, the evaluation of a debris index which assesses the environmental impact of spacecraft was conducted using the Near-Earth Orbital Debris Environment Evolutionary Model (NEODEEM). This study revealed the index would be able to assess the long- and short-term impact by weighting between the expected number of fragments exhausted from a target object and its orbital lifetime (Fig. 1). We also evaluated the shortening of the 25-year rule for post mission disposal (PMD) of a spacecraft. The results demonstrated the contribution of PMD compliance rate to long-term sustainability and the effects of shortening the rule on short-term safety (Fig. 2). These results are used to measure the effectiveness of debris mitigation and also used as a basis for discussing international rules.

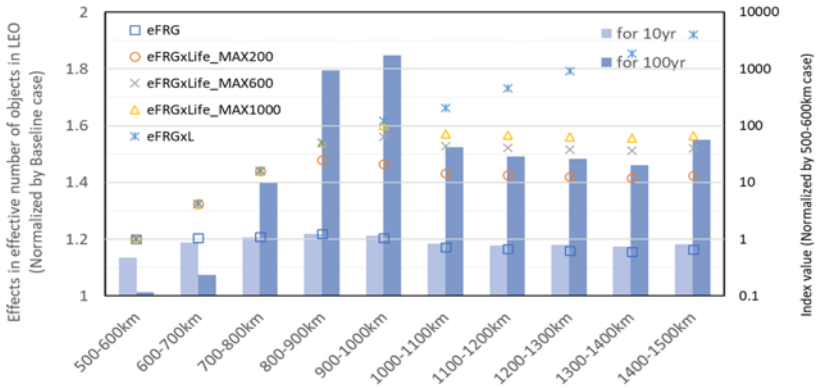

Fig. 1: The compariosn of debris index of an unctrolled larger cpnstellation satellites and the effects in effective number of objects (normalized by 500-600km case)

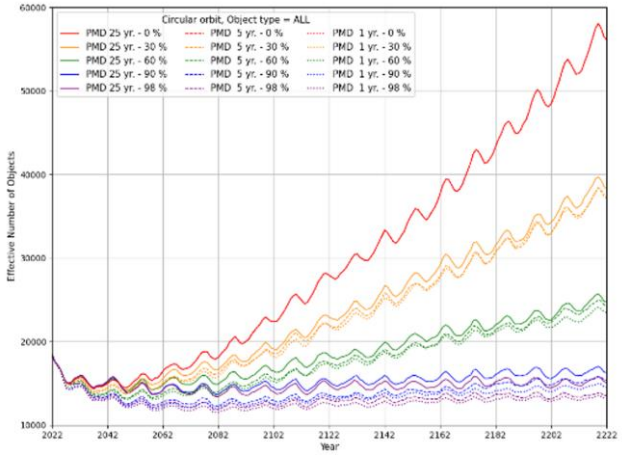

Fig. 2: The evolution of the number of objects in low earth orbit changing the PMD compliance rate and the PMD duration

Publications

- Peer-reviewed papers

1. Ryusuke Harada, Satomi Kawamoto, Nobuaki Nagaoka, and Toshiya Hanada, The Impact Assessment of Accidental Explosions of Large Constellations on Low Earth Orbit Environment, Journal of Space Safety Engineering, Volume 10, Issue 2, June 2023, Pages 256-263, https://doi.org/10.1016/j.jsse.2023.03.007

2. Ryusuke Harada, Satomi Kawamoto, Nobuaki Nagaoka, and Toshiya Hanada, Environmental Impacts of GTO Objects on LEO, Journal of Evolving Space Activities (in press)

- Non peer-reviewed papers

1. Ryusuke Harada, Satomi Kawamoto, and Toshiya Hanada, Establishment of Debris Index Evaluation Criteria and Comparison of Index Effects, 74th International Astronautical Congress (IAC), Bake, Azerbaijian, 2-6 October 2023.

2. Satomi Kawamoto, Ryusuke Harada, Yasuhiro Kitagawa, and Toshiya Hanada, Evaluation of the effectiveness of 5-year rule -- Impact of reducing post-mission disposal lifetime from 25 years to 5 years on the on-orbit

environment at each altitude, 74th International Astronautical Congress (IAC), Bake, Azerbaijian, 2-6 October 2023.

3. Ryusuke Harada, Satomi Kawamoto, and Toshiya Hanada, Assessments of the Impacts of Orbital Fragmentations using NEODEEM the Near-earth Orbital Debris Environment Evolutionary Model, Second International Orbital Debris Conference, Texas, United States of America, 4-7 December 2023.

4. SATO Kenichi, NITTA Kumi, YOSHIHARA Toru, HARADA Ryusuke, KAWAMOTO Satomi, IKEDA Hirohide, KINOSHITA Masahiro, UI Kyoichi, and MATSUURA Yoshiki, COLLISION PROBABILITY EVALUATION DURING ORBITAL LIFETIME OF SOLID ROCKET MOTOR SLAG, 12th International Association for the Advancement of Space Safety (IAASS), Osaka, Japan, 22-25 May 2023.

Usage of JSS

Computational Information

Process Parallelization Methods	Assigning Monte-Carlo runs with same initial conditions to multiple cores
Thread Parallelization Methods	N/A
Number of Processes	20 - 30
Elapsed Time per Case	72 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.39

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
TOKI-ST	3,075,139.81	3.32
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	1.71	0.00
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	0.00	0.00
/data and /data2	0.00	0.00
/ssd	0.00	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	39.30	0.14

*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.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2 (%)
ISV Software Licenses (Total)	0.00	0.00

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