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 been researching space debris related technologies for the space debris mitigation and environmental remediation. The effectiveness of space debris countermeasures are evaluated based on the prediction of the 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 40000 elements and orbital events by using Monte-Carlo method (evaluate the average of 100 runs). Therefore, JSS3 is used to reduce the computational 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 future orbital environment evaluations, the correlation between an orbital capacity that assesses the space sustainability quantitatively and debris indexes that measure the environmental impact of spacecraft was evaluated. The results implied the current and future orbital capacity can be assessed by weighting the debris indexes factors, the short-term impacts and long-term continuity of fragmentation, according to the altitude (Fig. 1). Reassessment of Active Debris Removal (ADR) targets was also conducted taking into account the latest orbital situation which includes the large constellations (LCs). The study showed that the large objects in higher altitudes with high collision probabilities should be removed to achieve the long-term stability even with the LCs (Fig. 2). These results are used to measure the effectiveness of debris mitigation and are also used as a basis for discussing international rules.

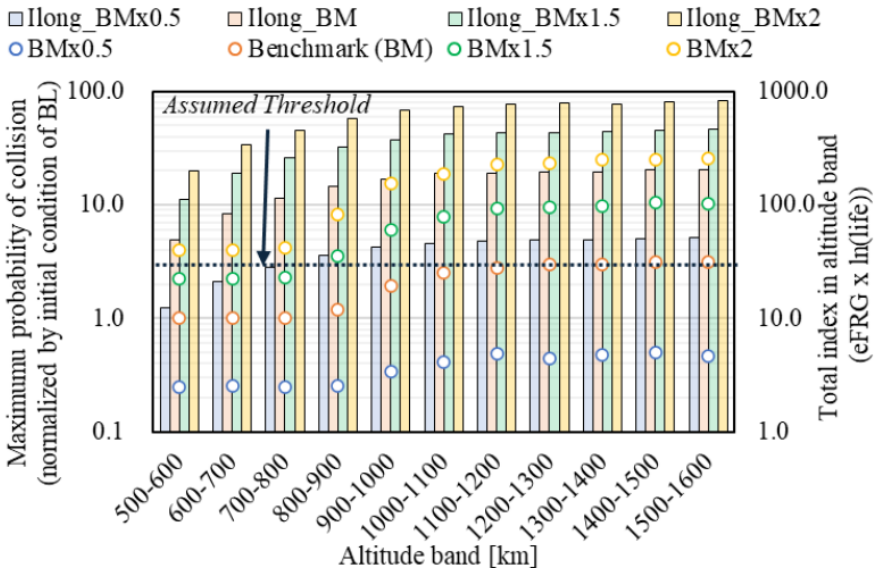

Fig. 1: Altitude distribution of Maximum cumulative collision probability: CPc (circles) and debris index (bars) changing the initial spatial density. Over capacity was defined as exceeding the assumed threshold of CPc, and the debris indexes were evaluated for its ability to predict the current and future status.

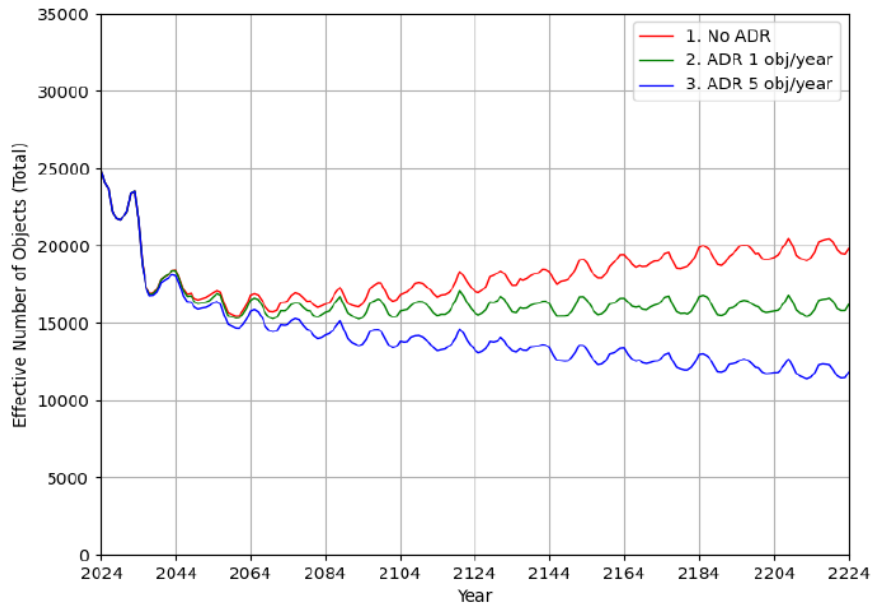

Fig. 2: Changes in the effevtive number of orbital objects in the case of no ADR and ADR of 1 and 5 object(s) per year

Publications

- Peer-reviewed papers

1. Ryusuke Harada, Satomi Kawamoto, and Toshiya Hanada, Establishment of debris index evaluation criteria

and comparison of index effects, Acta Astronautica

Volume 222, September 2024, Pages 586-595

2. Ryusuke Harada, Satomi Kawamoto, and Toshiya Hanada, Assessments of the impacts of orbital fragmentations using the Near-Earth Orbital Debris Environment Evolutionary Model (NEODEEM), Journal of Space Safety Engineering, Volume 11, Issue 3, September 2024, Pages 395-402

- Non peer-reviewed papers

1. Ryusuke Harada, Satomi Kawamoto, and Toshiya Hanada, Verification of correlation between a debris index and orbital environment evolution and considerations of capacity, 75th International Astronautical Congress (IAC), Milan, Italy, 14-18 October 2024.

2. Ryusuke Harada, Satomi Kawamoto, and Toshiya Hanada, Assessment of Correlations Between Debris Indexes and Orbital Capacity, 11th JAXA Space Debris Workshop, Chofu, Japan, 28-30 Oct. 2024

3. Satomi Kawamoto, Ryusuke Harada, Yasuhiro Kitagawa, and Toshiya Hanada, Reassessment of target objects and mission requirements for active debris removal due to changes in the on-orbit environment, 75th International Astronautical Congress (IAC), Milan, Italy, 14-18 October 2024.

4. Francesca Letizia, Camilla Colombo, Alessandro Rossi, Andrea Muciaccia, Lorenzo Giudici, Ryusuke Harada, Satomi Kawamoto, Lorenz Bottcher, Vincent Ruch, Christophe Taillan, Mission-based and environment-based approaches for assessing the severity of a space debris evolution scenario from a sustainability perspective, 75th International Astronautical Congress (IAC), Milan, Italy, 14-18 October 2024.

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](%): 0.13

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
TOKI-ST	1,121,669.80	1.15
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	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	44.36	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.