

B01

## 九州大学における宇宙デブリのモデリング Orbital Debris Modeling in Kyushu Univ.

丸山 貴大, 吉村 康広, ○花田 俊也(九州大学), 河本 聡美(JAXA)  
MARUYAMA Takahiro, YOSHIMURA Yasuhiro, ○HANADA Toshiya (Kyushu Univ.),  
KAWAMOTO Satomi (JAXA)

軌道環境推移モデルの構築により, どのようにすれば宇宙デブリを低減し, 軌道環境を改善することができるのか, を議論することができる. よりよい議論を行うためには, 推移モデルの推定精度の向上が不可欠である. 現在の推移モデルに実装されている衝突破砕モデルでは, 衝突の際に生じる破片の分布が, 質量の大きい方の物体に依存しており, やや現実性に欠けている. そこで, 本講演では, 衝突の際に生じる破片がどちらの物体から生じた破片なのかを判別し, 両物体の周りに破片の分布を形成する手法を提案する. また, 本講演では, 衝突破砕モデルの改良前後の将来予測結果を比較し, 衝突破砕モデルの改良がもたらす軌道環境の変化について考察したことを述べる.

The building of space debris evolutionary models makes it possible to discuss how to reduce space debris and improve future orbital environment. In order to have a better discussion, it is essential to improve the accuracy of estimation in space debris evolutionary models. In collision breakup models implemented in current space debris evolutionary models, it is somewhat unrealistic that the distribution of fragments generated during a collision depends on the primary object. Therefore, this paper proposes a method to determine which object generated each fragment and form the distribution of fragments not only around the primary object but also around the secondary object. This paper also compares future orbital environment before and after the improvement of collision breakup models and describes differences of future orbital environment by improved collision breakup models.



# 九州大学における宇宙デブリのモデリング

## Orbital Debris Modeling in Kyushu Univ.

丸山 貴大, 吉村 康広, 花田 俊也 (九州大学), 河本 聡美 (JAXA)  
Takahiro Maruyama, Yasuhiro Yoshimura, Toshiya Hanada (Kyushu Univ.), Satomi Kawamoto (JAXA)

The 9th JAXA Space Debris Workshop  
February 25, 2021



KYUSHU UNIVERSITY



KYUSHU UNIVERSITY

Orbital Debris Modeling in Kyushu Univ.



## Orbital Debris Modeling

Orbital debris modeling mainly consists of **debris generation** and **orbit propagation**.

- Debris generation can characterize and predict physical properties of fragments originating from explosions or collisions.
- Orbit propagation can characterize, track and predict the behavior of space objects.

## Evolutionary Models

With collision flux estimation, orbital debris modeling can build **evolutionary models** as essential tools:

- to predict the current or future space debris environment, and also
- to discuss what and how to do for space debris mitigation and environmental remediation.

## Evolutionary Models in Kyushu Univ.

GEODEEM (GEO space Debris Environment Evolutionary Model)

- To track objects in the Geostationary region (or with eccentricity  $< 0.2$ , mean motion between 0.9 and 1.1 rev. per day, and inclination  $< 30$  deg).

LEODEEM (Low Earth Orbital Debris Environment Evolutionary Model)

- To track objects in the low Earth orbit region (or with perigee altitude  $< 2000$  km ).

**NEODEEM** (Near-Earth Orbital Debris Environment Evolutionary Model)

- To track objects orbiting around the Earth.



## NEODEEM revision 3.02.1

### Debris generation

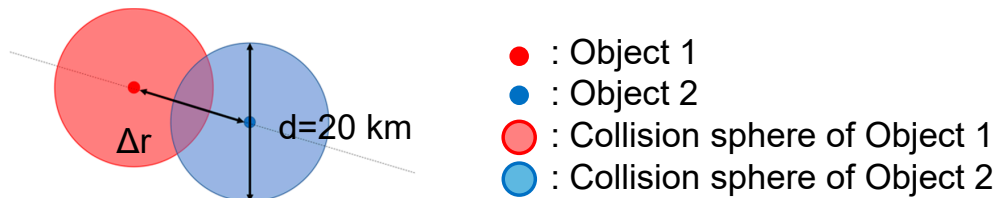
- NASA Standard Breakup Model of EVOLVE 4.0
  - A/M distribution proposed by Anz-Meador and Matney

### Orbit propagation

- First-order solution
- Zonal harmonics ( $J_2, J_3, J_4$ ), Solar-Radiation Pressure, Sun, Moon, Atmospheric Drag (Jacchia-Roberts 1971, Jacchia-Bowman 2008)

### Collision flux estimation

- Two-Sphere collision probability estimation (T-Scope)



9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

4



## Improvements of NEODEEM

In order to have a better discussion, it is essential to improve the accuracy of estimation in evolutionary models.

### NEODEEM plans to

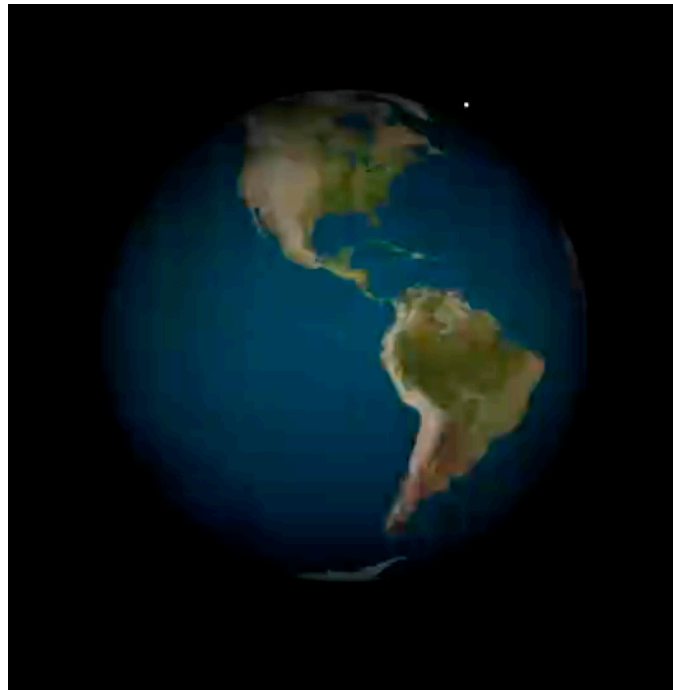
- Revise collision breakup models that the distribution of fragments generated during a collision spreads only around **the primary object**.
- Implement **STELA Drag Coefficient**, which is drag coefficient corresponding to the **altitude**.

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

5



## Distribution of Fragments



9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

6



## Objectives

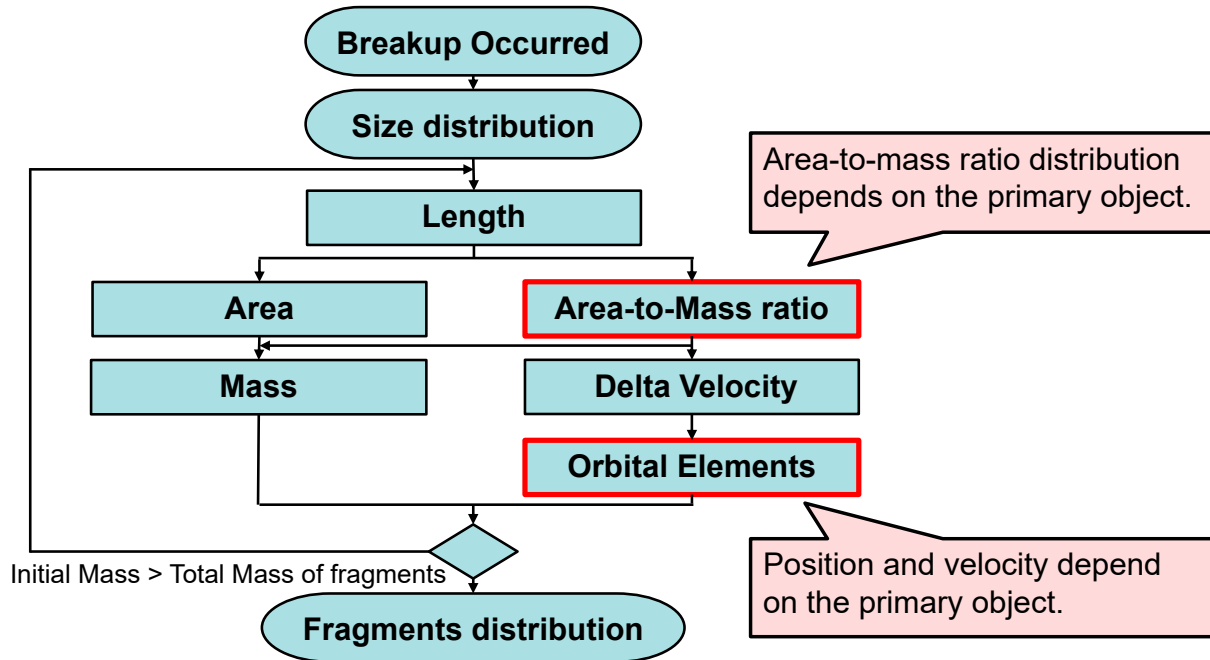
- Proposing a method to determine **which object generated each fragment.**
- Forming the distribution of fragments around both **primary and secondary** objects.
- Comparing future orbital environment **between previous and revised** collision breakup models.

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

7



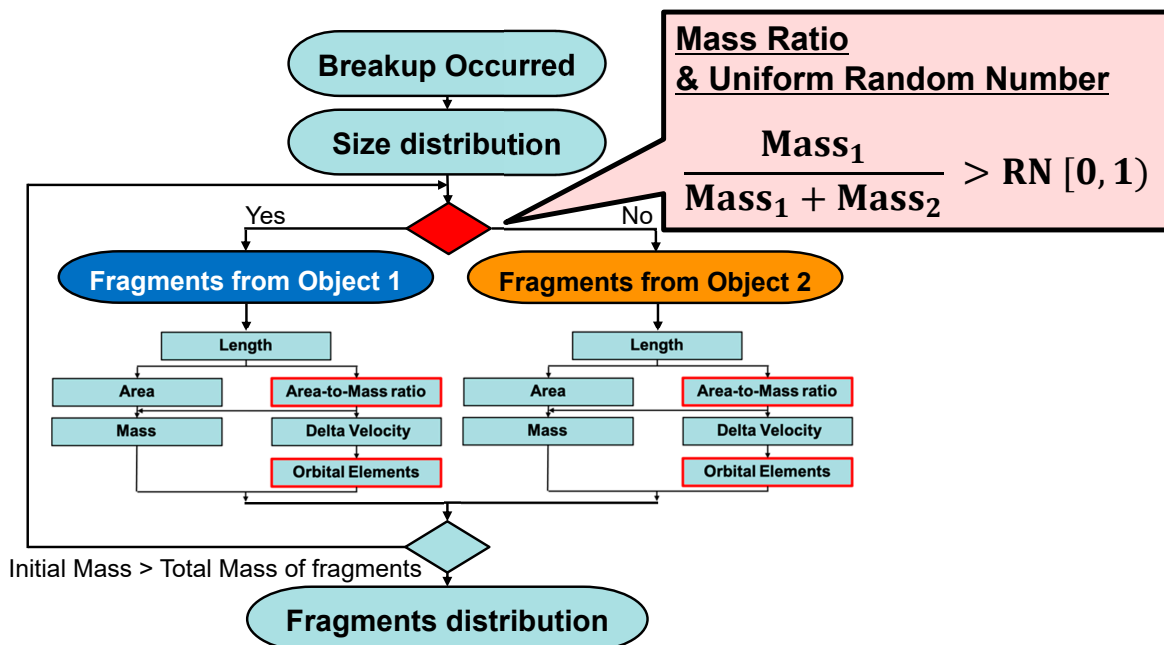
## Previous Collision Breakup Models

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

8



## Revised Collision Breakup Models

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

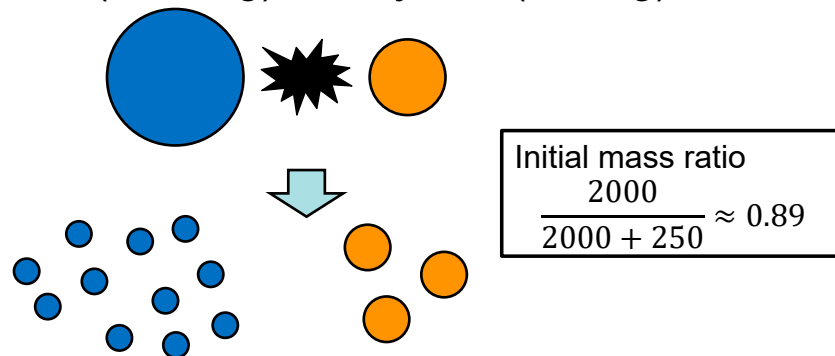
9



## Concerns

The mass distribution of the fragments may be biased when objects have a large mass difference.

Example) Object 1 (2000 kg) vs Object 2 (250 kg)

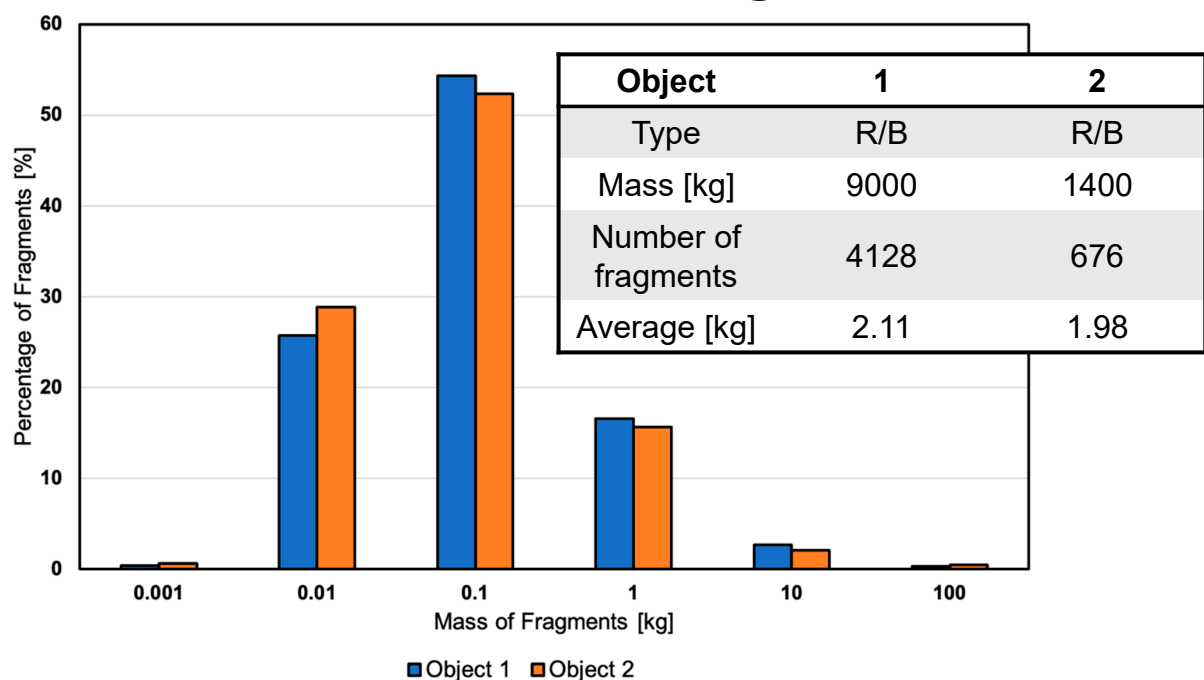


9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

10



## Mass Distribution of Fragments

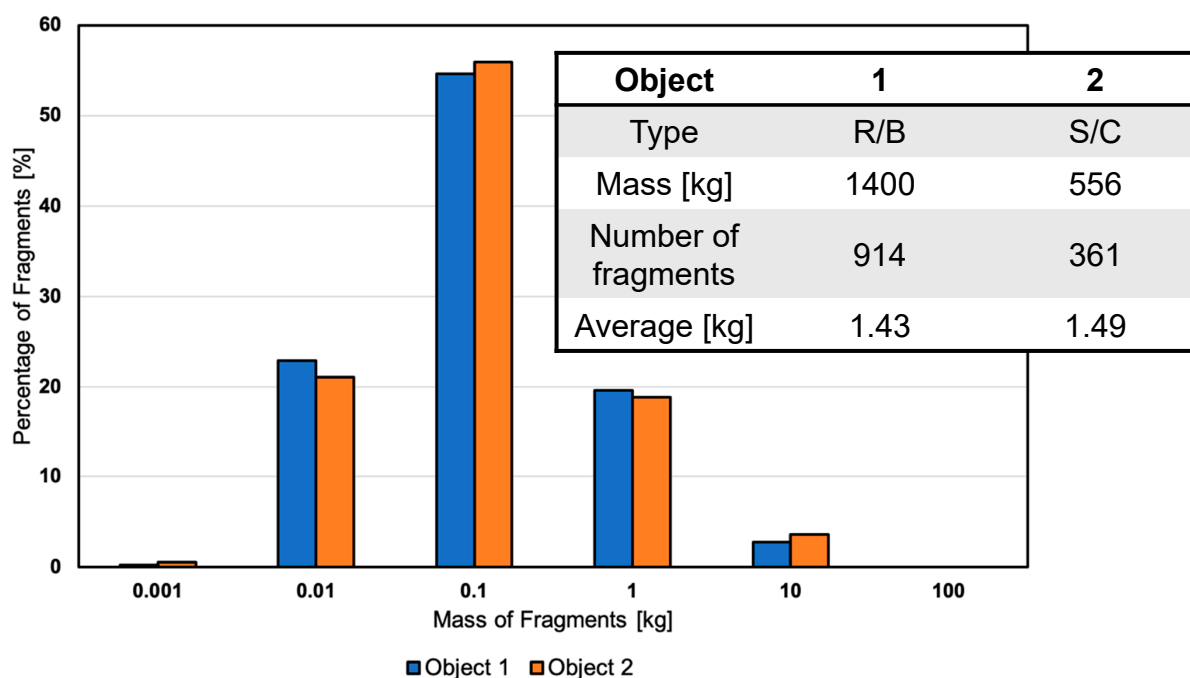


9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

11



## Mass Distribution of Fragments

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

12



## Comparing Distribution of Fragments

[Previous model]

[Revised model]

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

13





## Conditions of the Simulation

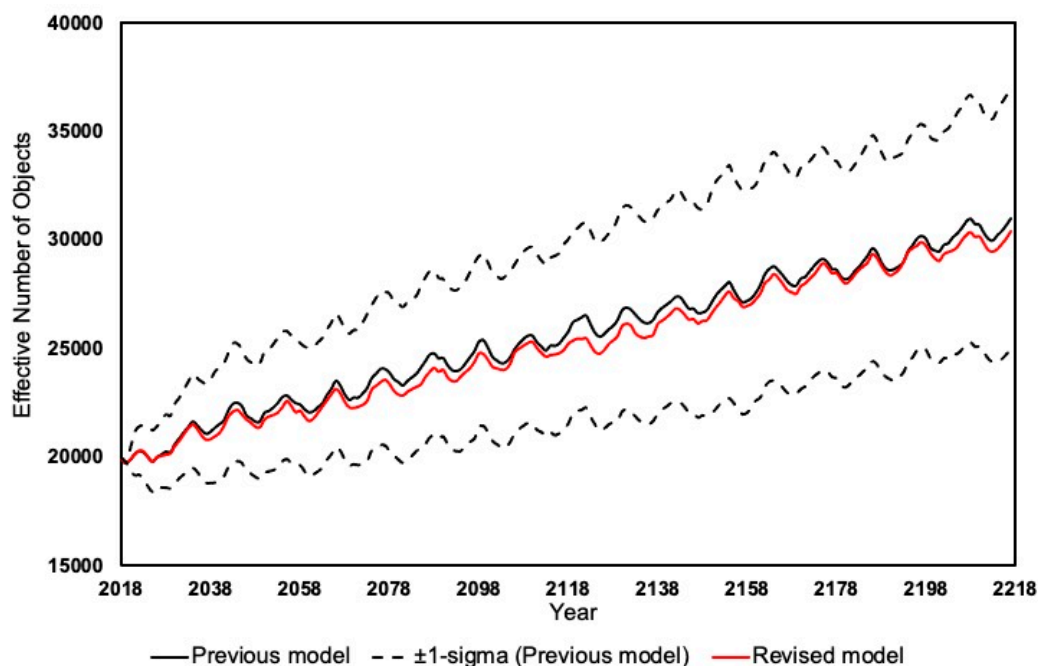
Initial Population	As of February 1, 2018
Space Activities	New Launches (8-year cycle) (2010 – 2017) PMD (90%)
Debris Generation	Collision
Projection Span	2018 ~ 2217
Minimum Size	10 cm
Monte Carlo Runs	100
Time Step	5 days
Events Evaluation	Every 1 year

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

14



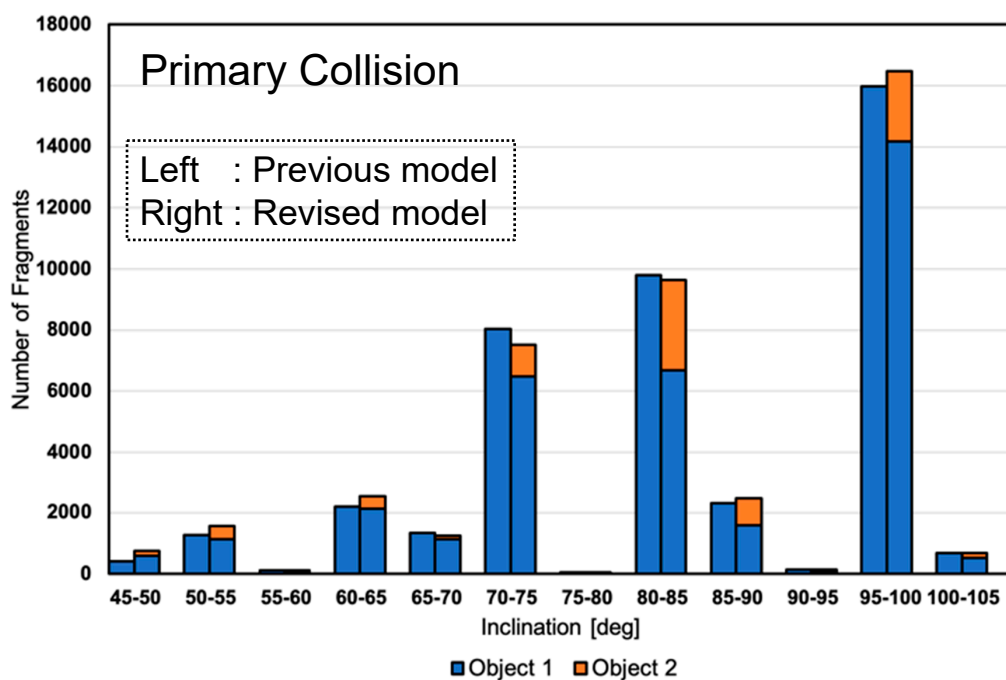
## Effective Number of Objects

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

15



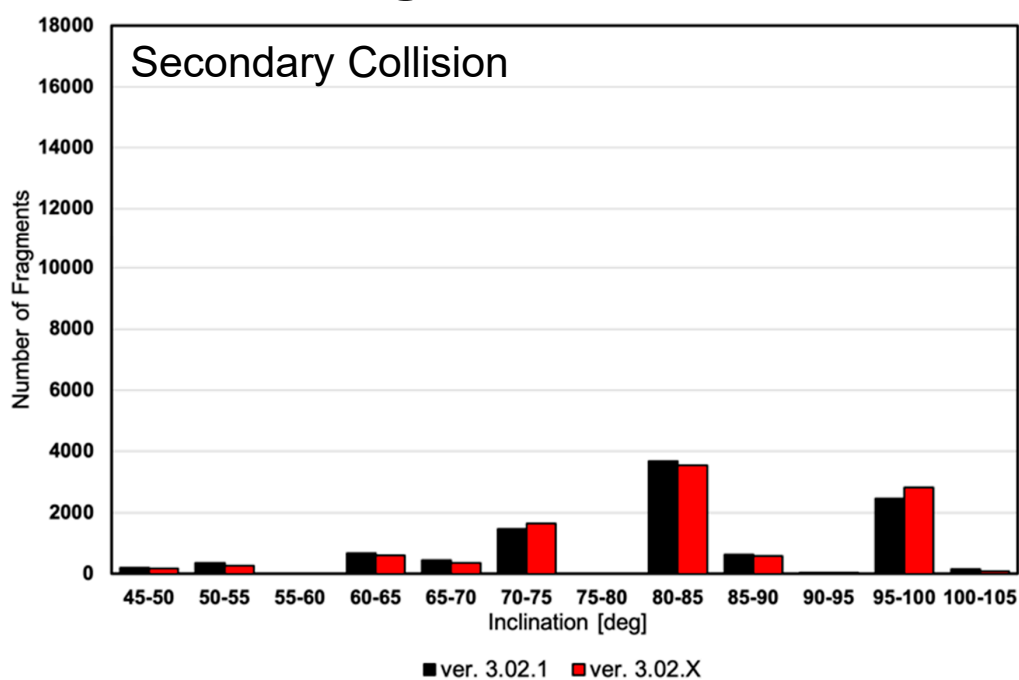
## Number of Fragments

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

16



## Number of Fragments

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

17



## Conclusions

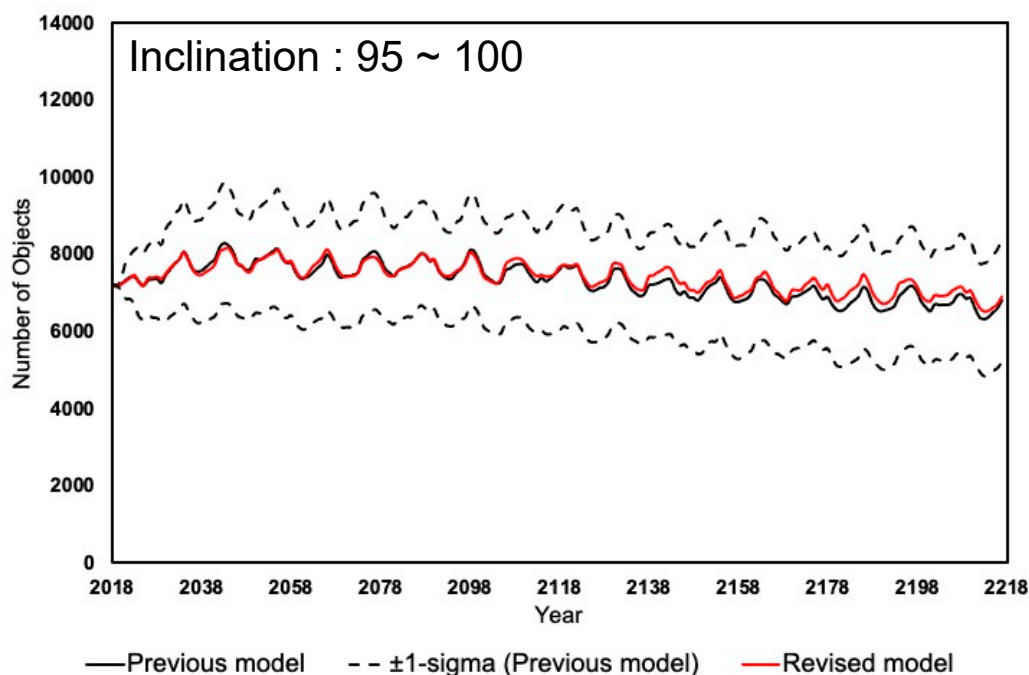
- This paper briefly introduced efforts to orbital debris modeling.
- Mass ratio and uniform random number were able to determine **which object generated each fragment**.
- The distribution of fragments was formed around both **primary and secondary** objects.
- There were **no significant differences** in the transition of the number of objects.
- These results supported the significance of past analyzes.

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

18



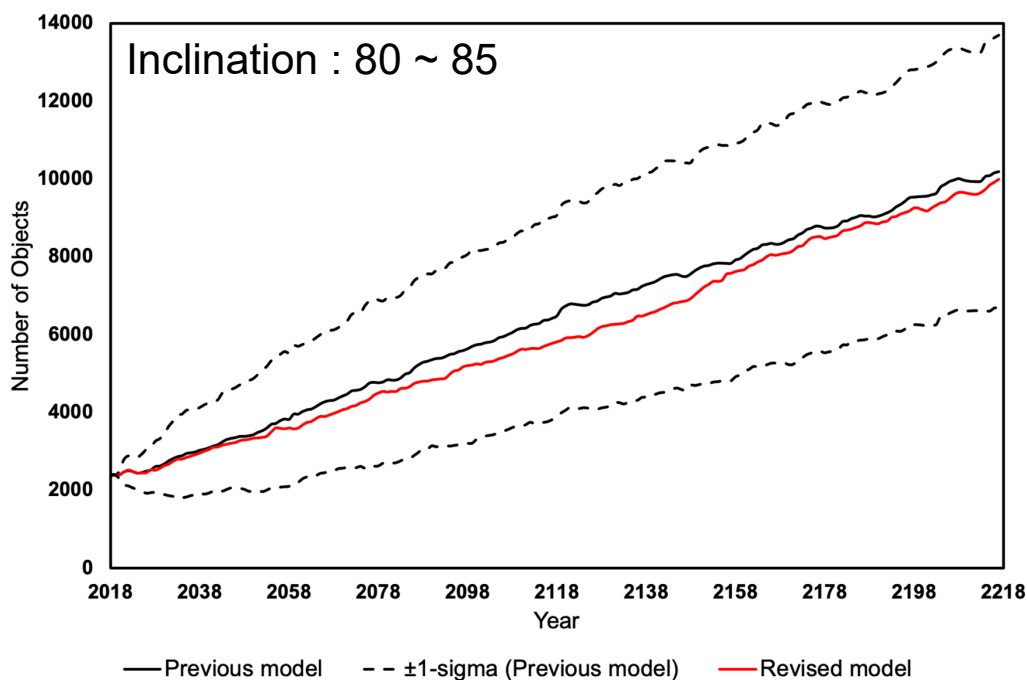
## Number of Objects

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

19



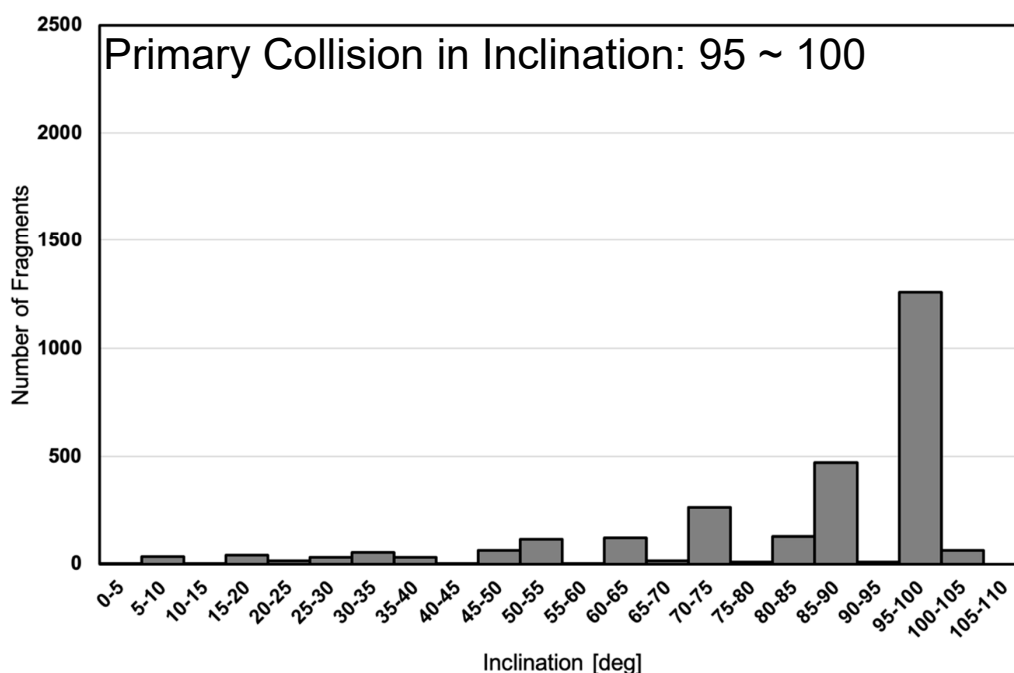
## Number of Objects

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

20



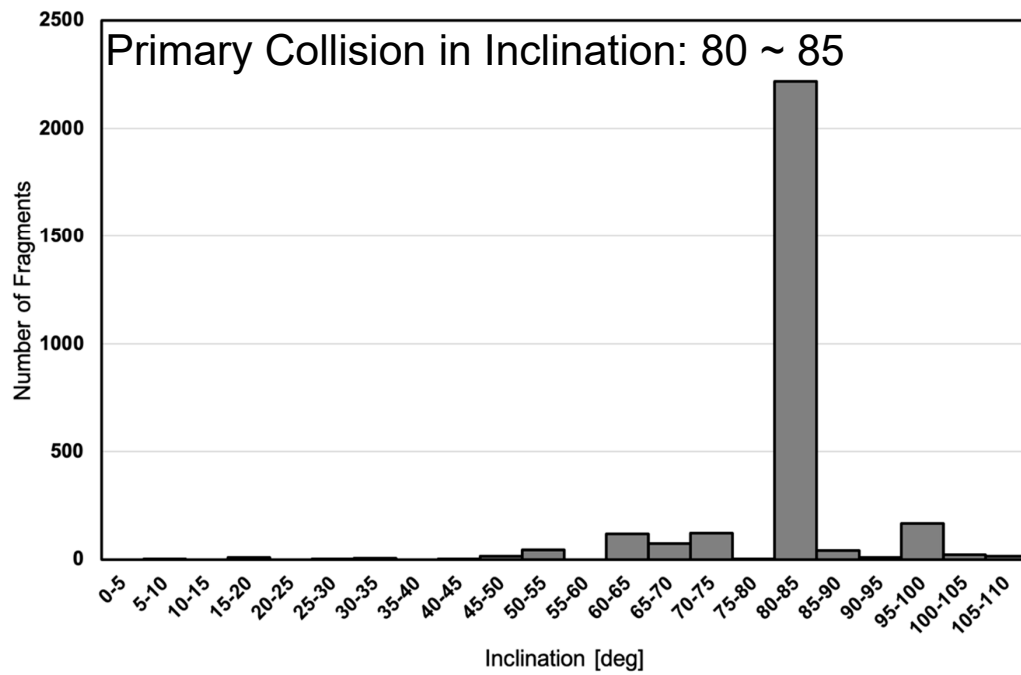
## Number of Fragments

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

21



## Number of Fragments

9<sup>th</sup> Space Debris Workshop (Dec. 8, 2020)

22