C03

デブリ衝突損傷リスク解析ツール TURANDOT の現状と改修計画

Present Status and Improvement Plans of Tactical Utility for Rapid ANalysis of Debris on Orbit Terrestrial (TURANDOT)

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本講演では，デブリ衝突損傷リスク解析ツール（TURANDOT）の概要と今後の改修計画を紹介する．TURANDOT は，JAXA で開発された宇宙機設計支援ソフトウェアである． 本ツールは宇宙機表面を詳細な格子に分割し，デブリに対する宇宙機自身の遮蔽を考慮した上で，各部位のデブリ衝突頻度を解析可能である．また，任意の宇宙機部位について，宇宙機表面材料と弾道方程式を設定することで，損傷リスクも評価可能である． さらに，メテオロイドのエンジニアリングモデルを用いることで，デブリと同様の解析が可能であり，ESA MASTER-2009 と NASA MEMR2 に対応している．現在，解析可能な軌道は GEO までの地球周回軌道に限られるが，MEMR2 は月周辺のメテオロイド環境を解析可能であるため，月面ならびに月周回軌道の解析を可能とする改修を検討中である． 加えて，対応しているエンジニアリングモデルをアップデート中である（NASA ORDEM 3.1，MEM 3）． 更に，原子状酸素の影響評価と月面における日照解析への応用を検討している．

We introduce overview and improvement plans of Tactical Utility for Rapid ANalysis of Debris on Orbit Terrestrial (TURANDOT). TURANDOT is developed by JAXA to assist the users for spacecraft design. The software is capable of prediction of probability of debris impact to a spacecraft including shielding effect of the spacecraft itself. In addition, corresponding damage risk can be evaluated by setting up the spacecraft surface materials and ballistic limit equations for a given spacecraft part. Furthermore, the software provides risk assessments not only for debris but also for meteoroids by applying engineering models of meteoroid and supports two models: ESA MASTER-2009 and NASA MEMR2. At present, TURANDOT can analyze the risks on the orbits around the Earth up to GEO, but we are planning to improve the software to enable analysis for the lunar surface and for the lunar orbits using MEMR2, which provides the meteoroid environment data around the Moon. In addition, an updating supporting engineering models is in progress: NASA ORDEM 3.1 for debris and NASA MEM3 for meteoroid. Moreover, an expansion of the application is being considered - analyzing the effect of atomic oxygen erosion on material and estimation of the solar irradiance that reaches objects on the Moon, for example.

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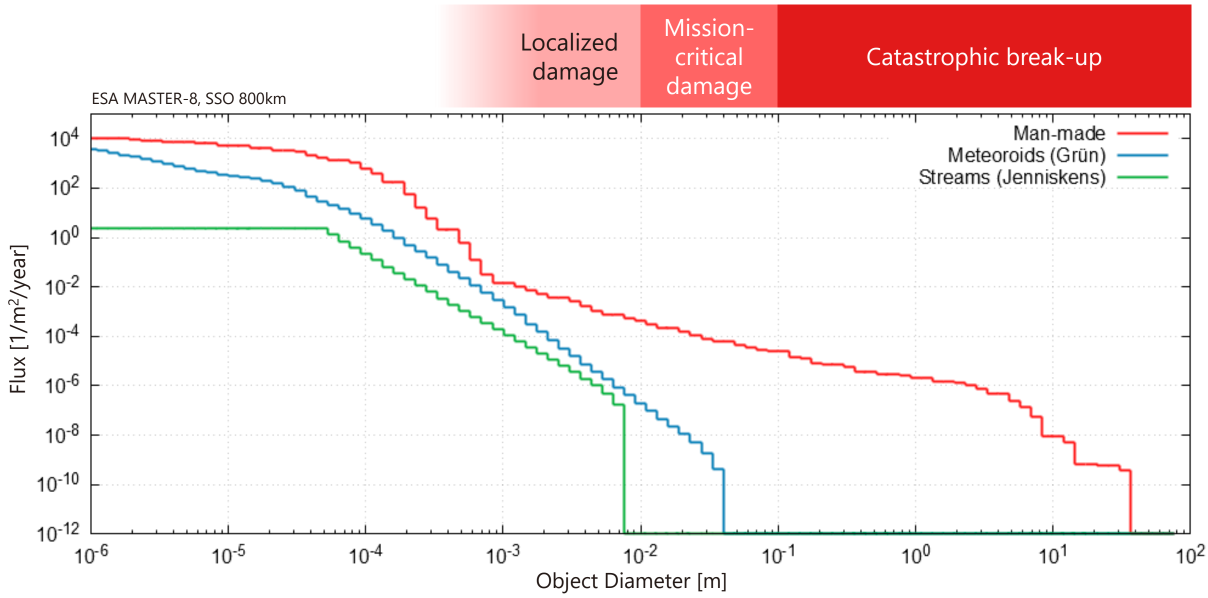
- Overview of TURANDOT
- What’s new on TURANDOT
- Planning enhancements
- Conclusion

Introduction

Meteoroid/Orbital Debris Risk



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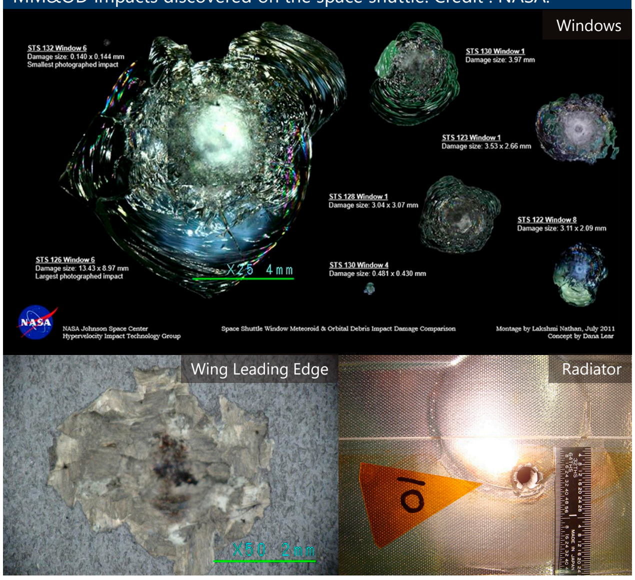
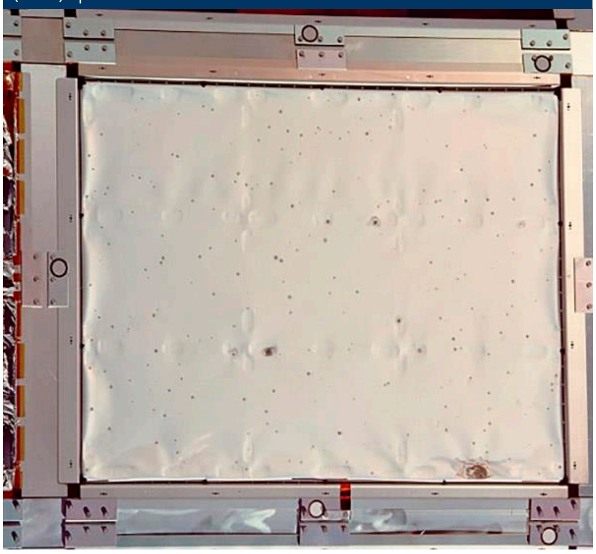
Introduction

Meteoroid/Orbital Debris Risk

MM&OD impacts discovered on the space shuttle. Credit : NASA.



A close-up view of a panel from the Long Duration Exposure Facility (LDEF) spacecraft. Credit : NASA JSC.



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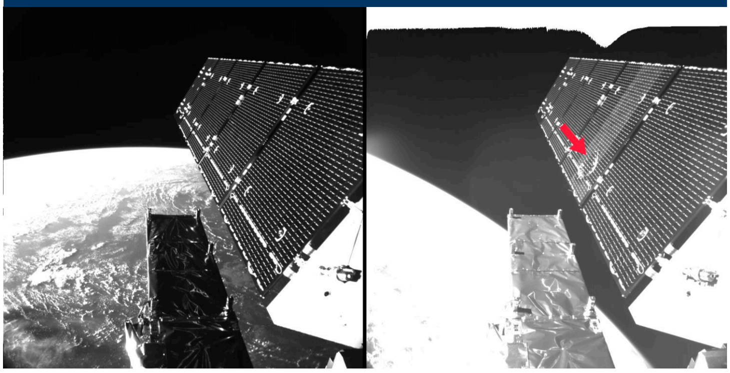
Introduction

Meteoroid/Orbital Debris Risk

Sentinel-1 impact. Credit : ESA.



Impact-induced sustained discharge on power harness (ground experiment)

HIRAI Takayuki et al.,
The 7th Space Debris Workshop (2016)

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Introduction

Meteoroid/Orbital Debris Risk Assessment Tools

Tool	Space agency
BUMPER II	NASA
ESABASE2 / DEBRIS, PIRAT	ESA
COLLO, BUFFER	ROSCOSMOS
MDPANTO	DLR
SHIELD	BNSC
MODAOST	CAST
TURANDOT	**JAXA**

IADC Protection Manual(Version 7.1), IADC-04-03

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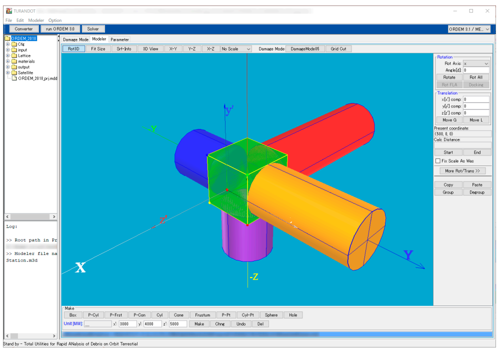
TURANDOT

- assesses Impact Flux, Impact Frequency and Impact Damage.
- takes shielding effect into account.
- supports ESA MASTER-2009, NASA ORDEM 3.0 and NASA MEMR2.

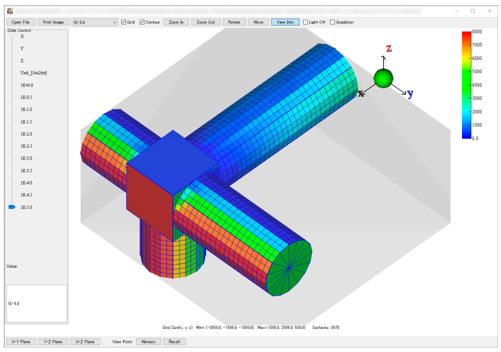
■ Layout of sensitive or critical equipment
■ Effectiveness of protection
■ Attitude of spacecraft
■ Inquiry of causes of failure

Integrated Analysis Environment

- Spacecraft modeling
- Grid generation
- Analysis condition setting



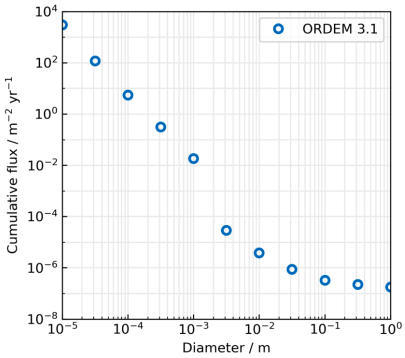
Modeling



Collision flux distribution

What's new on TURANDOT

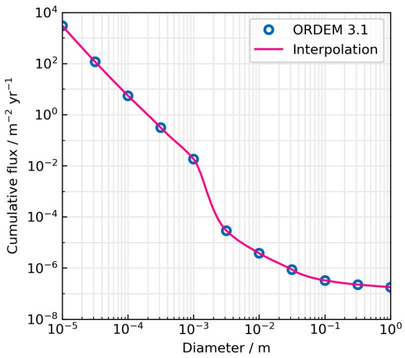
- Engineering model
  - ESA MASTER-2009 (Debris / Meteoroid)
  - NASA ORDEM 3.0 (Debris)
  - NASA MEMR2 (Meteoroid)
- Central body
  - Earth
- Size thresholds for ORDEM
  - 11 size thresholds



What's new on TURANDOT

What's new on TURANDOT

- Engineering model
  - ESA MASTER-2009 (Debris / Meteoroid) → **MASTER-8**
  - NASA ORDEM 3.0 (Debris) → **ORDEM 3.1**
  - NASA MEMR2 (Meteoroid) → **MEM 3**
- Central body
  - Earth + **Moon, Mars (Meteoroid)**
- Size thresholds for ORDEM
  - 11 size thresholds → **51**

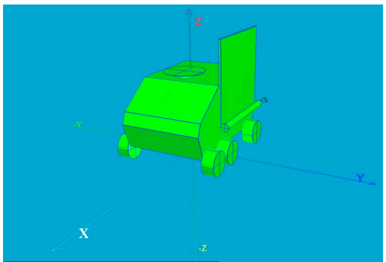


Planning enhancements

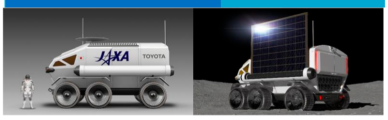
Application for Meteoroid around The Moon 1/2

Example:

- A Moon rover
- Flux of MEMR2 by NASA
  - JD 2462502.5 (2030-01-01T00:00:00.0)
  - 0° lon., -89.5° lat. (15km apart from the pole)
  - 10^{-6} g < *m* (124 μm < *d*)

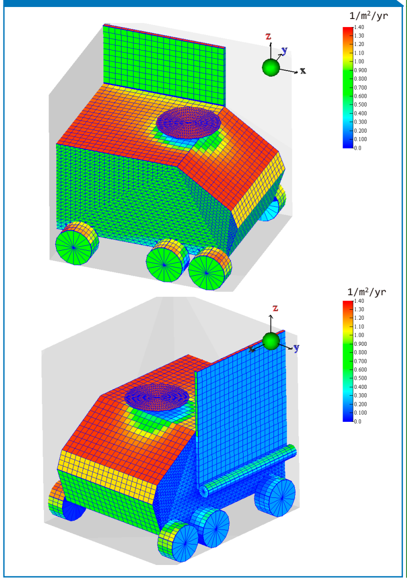


Analysis model by GUI

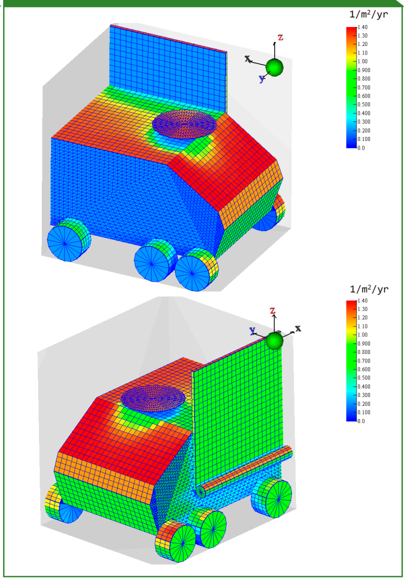


https://www.jaxa.jp/press/2019/03/20190312a_j.html

Advance direction: Sym-rotation



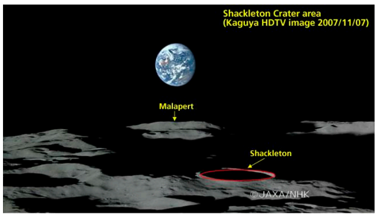
Advance direction: Anti-rotation



Planning enhancements

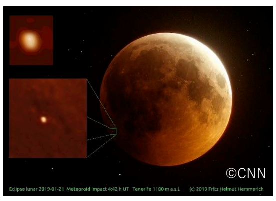
Application for Meteoroid around The Moon 2/2

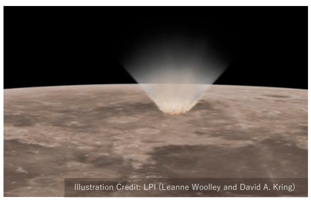
- Available for new materials as long as BLE is defined.
- The south pole of the Moon is rough terrain.
- Geographical shielding effect is to be introduced.



- Effect of ejecta by meteoroid can be analyzed, if corresponding flux is obtained.

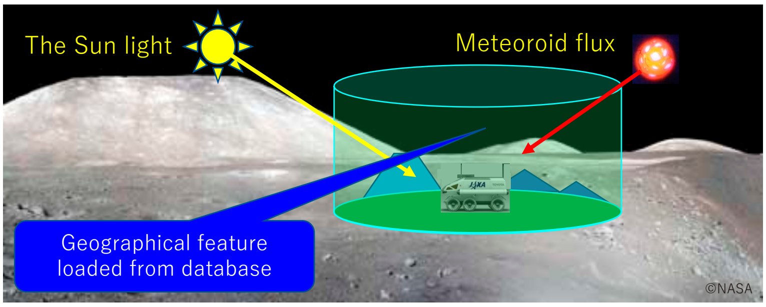
Collison during total lunar eclipse
E = 1.5×10^9 J
≒TNT350kg





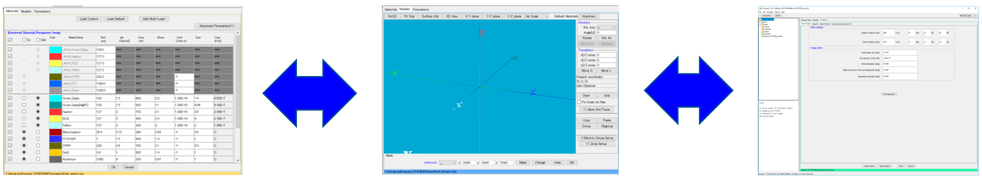
Analysis for the Sunshine or the Sunshade

- The Sunlight can be analyzed instead of meteoroid.
- Available for power generation.
- Reflection from the Moon surface may not be negligible because the solar elevation is very small around the south pole.



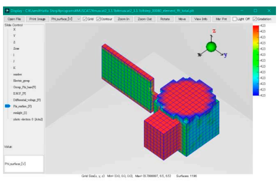
Application for AO Analysis –TURANDOT& MUSCAT-

- MUSCAT (charging analysis tool) was used in the past. [1]
- Common technology is used for both software. (Java® & Java3D®)
- GUIs are not common.

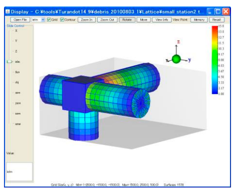


MUSCAT: charging property   Not same but similar GUI   TURANDOT: orbit/BLE

- Computation lattice is different
  - TURANDOT: along the surfaces
    - The collision angle can be exact.
  - MUSCAT: orthogonal lattice
    - The collision angle can be moderate.



MUSCAT

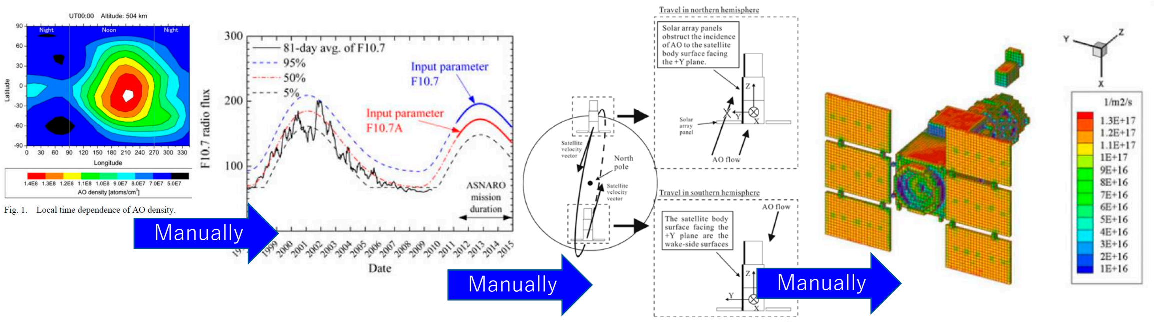


TURANDOT

[1]Ref. Iwata., M, et. al, "Analysis of Atomic Oxygen Fluence Distribution on Satellite Surface," Proceedings of ISTS2011 r-44/Trans. JSASS Aerospace Tech. Japan Vol. 10, pp. 5-9, 2012.

Application for AO Analysis

- An example of AO analysis by MUSCAT
- Technique of treating AO as ion of zero charge.
    - Introducing AO environment, application for MUSCAT were all manually conducted.
    - Limit by equally spaced orthogonal lattice. Small components was not simulated.



- Expansion of TURANDOT can reasonably provide analysis environment easy to use.

Conclusion

- An overview of TURANDOT and its improvement plans were presented.
- The potential for enhancement of TURANDOT were presented.
- Should you have any request, please feel free to contact us.