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デブリ衝突損傷リスク解析ツール TURANDOT の開発状況

Status of development of the Tactical Utilities for Rapid ANalysis of Debris on Orbit Terrestrial (TURANDOT)

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デブリ衝突損傷リスク解析ツール (TURANDOT) は, 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する. さらに, 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. 軌道上デブリフラックスのデータベースとして MASTER-2009 と ORDEM 3.0 をユーザが必要に応じて選択し, 利用できるように機能を拡張した. 損傷リスクを評価する宇宙機表面材料と弾道方程式については, 利便性を考慮し, 標準的な材料とモデルをツール内に組み込み, ユーザがパラメータを入力することのみで解析できるように機能を拡張した. さらに, STEP 形式で作成された衛星モデルを TURANDOT に取り込めるように STEP 形式の読み込み機能を強化した.

この講演では, 本ツールの概要と機能について紹介する.

Tactical Utilities for Rapid ANalysis of Debris on Orbit Terrestrial (TURANDOT) supports design of spacecrafts. The software is capable of damage probability prediction of a spacecraft caused by collisional debris including self-shielding effect of the spacecraft. Users can choose MASTER-2009 or ORDEM 3.0 as database of debris flux. New easy-to-use graphical interface already set up with ballistic limit equations. Furthermore, TURANDOT was improved reading functions of STEP (Standard for the Exchange of Product data) files. Overview and features of TURANDOT are introduced in the presentation.

TURANDOT

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Introduction

M/OD risk assessment tools	
BUMPER II	NASA
ESABASE2 / DEBRIS	ESA
COLLO, BUFFER	TSNIIMASH
MDPANTO	DLR
SHIELD	QinetiQ
MODAOST	CAST
TURANDOT	JAXA

IADC Protection Manual (Version 7.0), IADC-04-03
<https://www.nasa.gov/centers/johnson/techtransfer/technology/MSC-23774-1-bumper.html>
 Update of the ESA Space Debris Mitigation Handbook, ESA Contract 14471/00/D/HK

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About TURANDOT

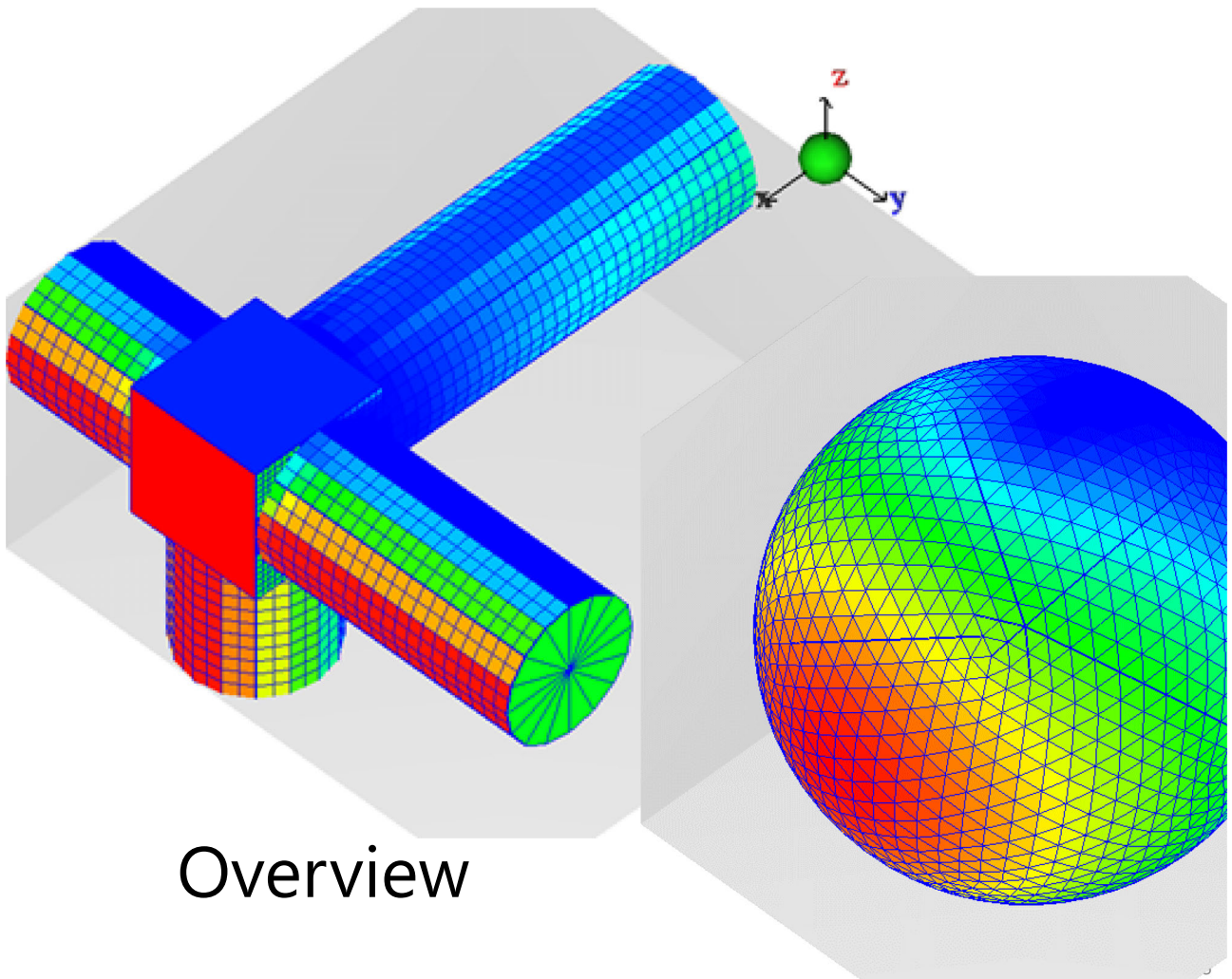
- TURANDOT supports design of spacecraft.
- The software is capable of prediction of spacecraft damage probability caused by collisional debris including shielding effect of the spacecraft itself.
- April, 2007~
 - “Collision Probability” Analysis Tool
 - “Collisional Damage” Probability Analysis Tool
 - Including “MASTER-2009” and “ORDEM 3.0”
 - Detail Modifications & Validations

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What's New

- The development language is Java only.
- New features
 - Choice of database of debris flux : MASTER-2009 or ORDEM 3.0.
 - A new easy-to-use graphical interface already set up with ballistic limit equations.
- Improvement
 - Reading functions of STEP (Standard for the Exchange of Product data) files.

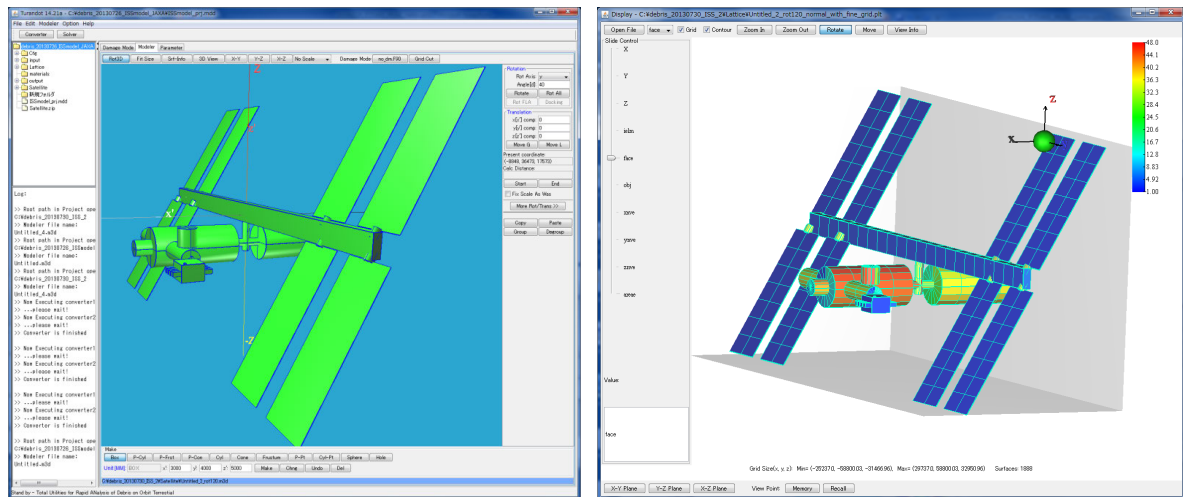
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Overview

Integrated Analysis Environment

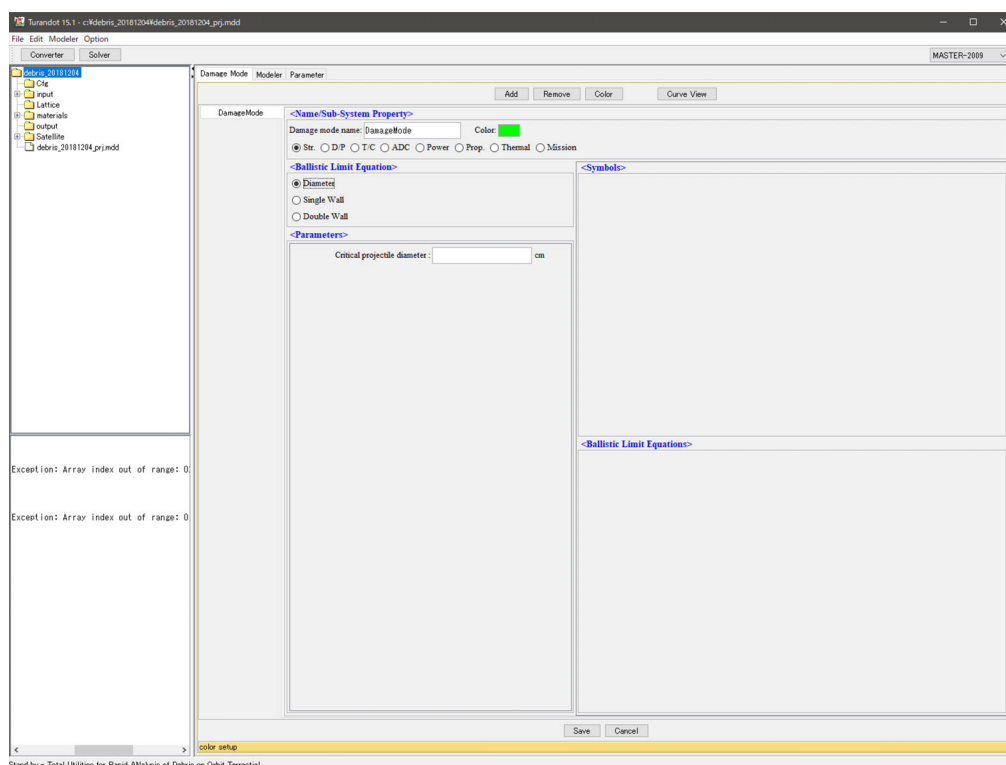
- GUI
 - Satellite modeling
 - Grid generation
 - Analysis condition setting



Acknowledgement for Kurihara, M.

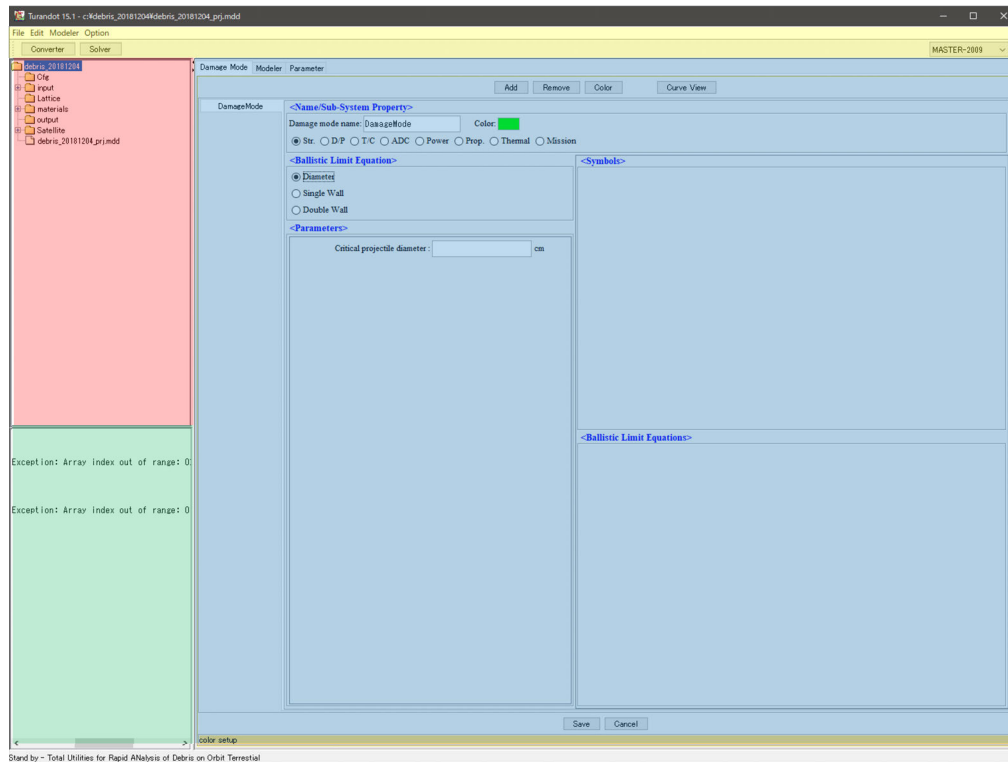
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TURANDOT GUI



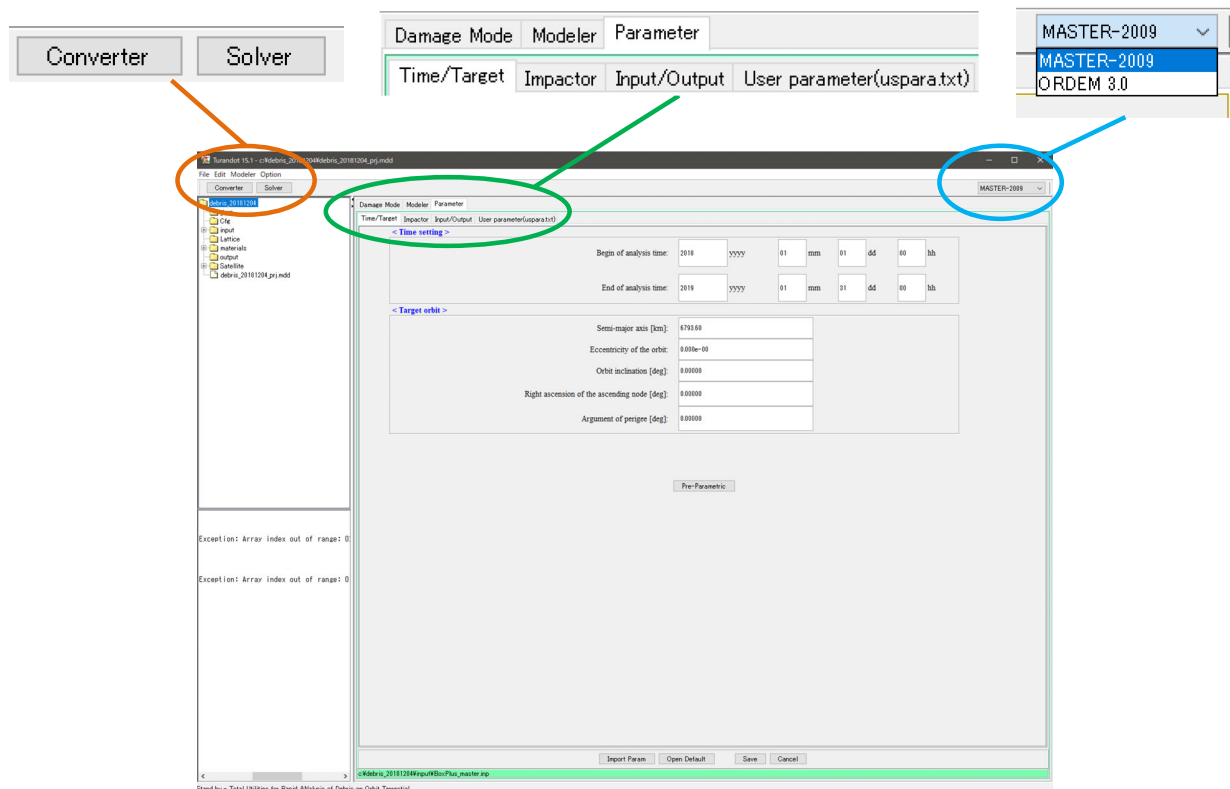
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TURANDOT GUI



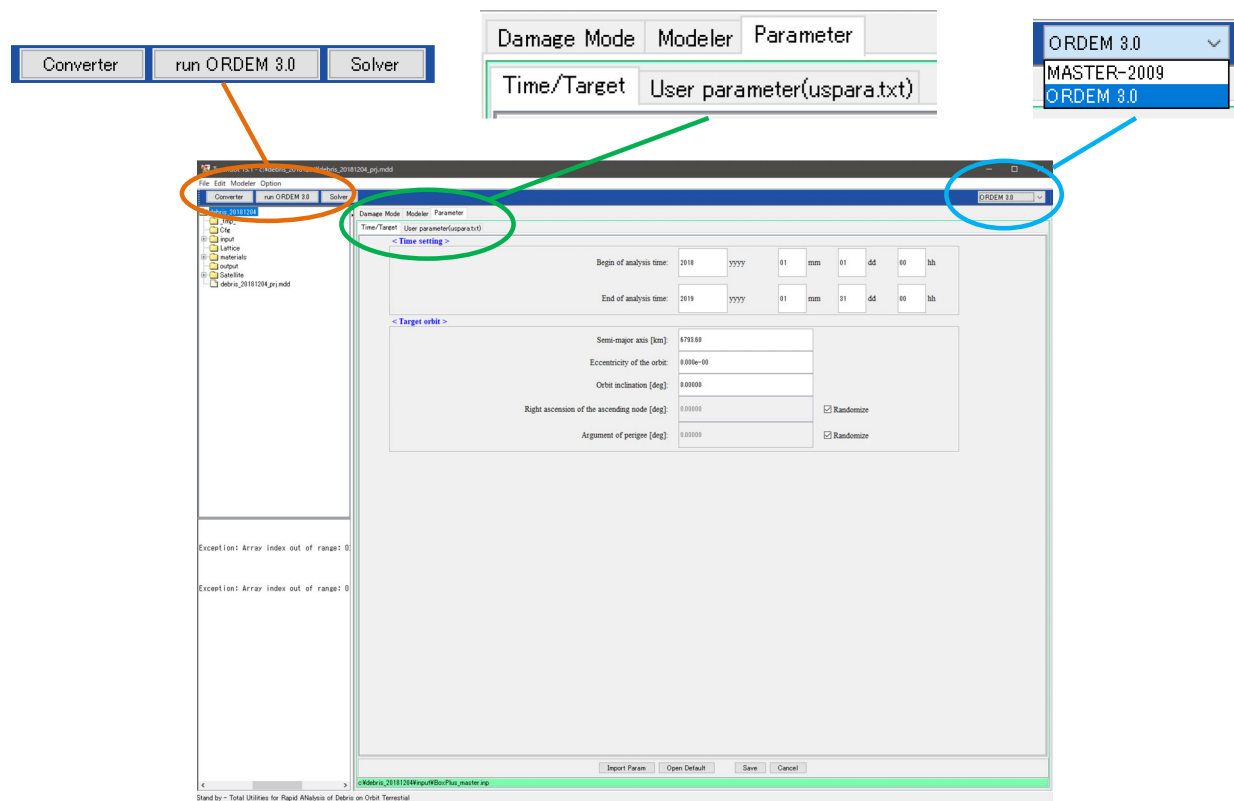
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TURANDOT GUI : MASTER



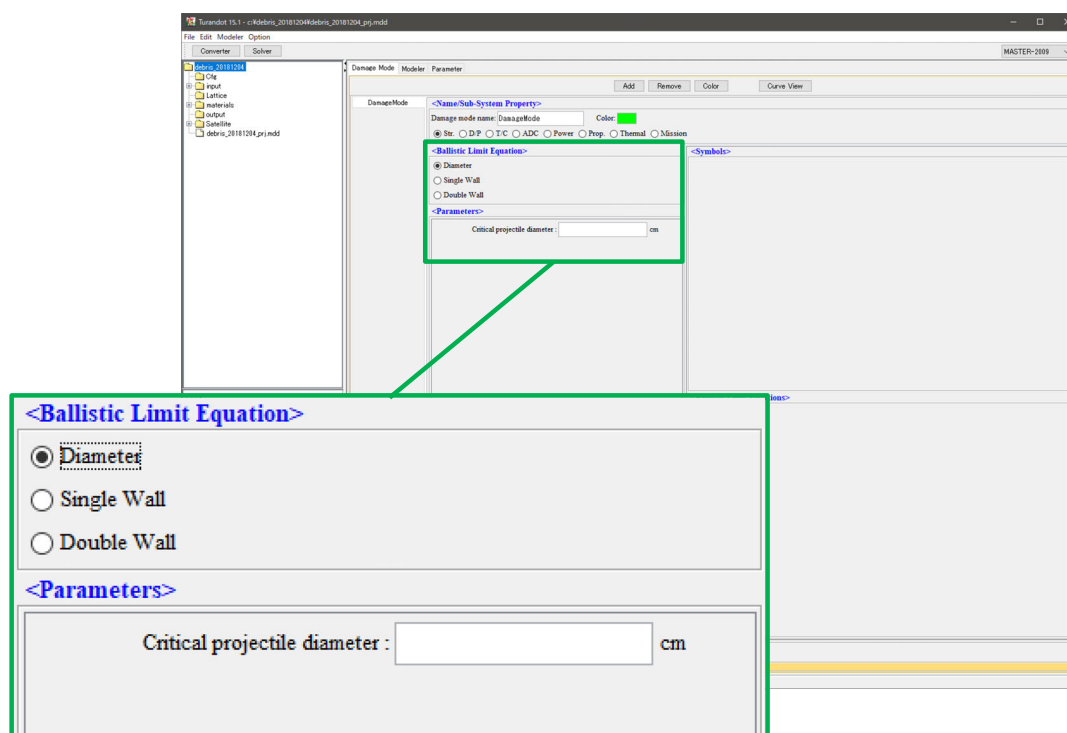
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TURANDOT GUI : ORDEM



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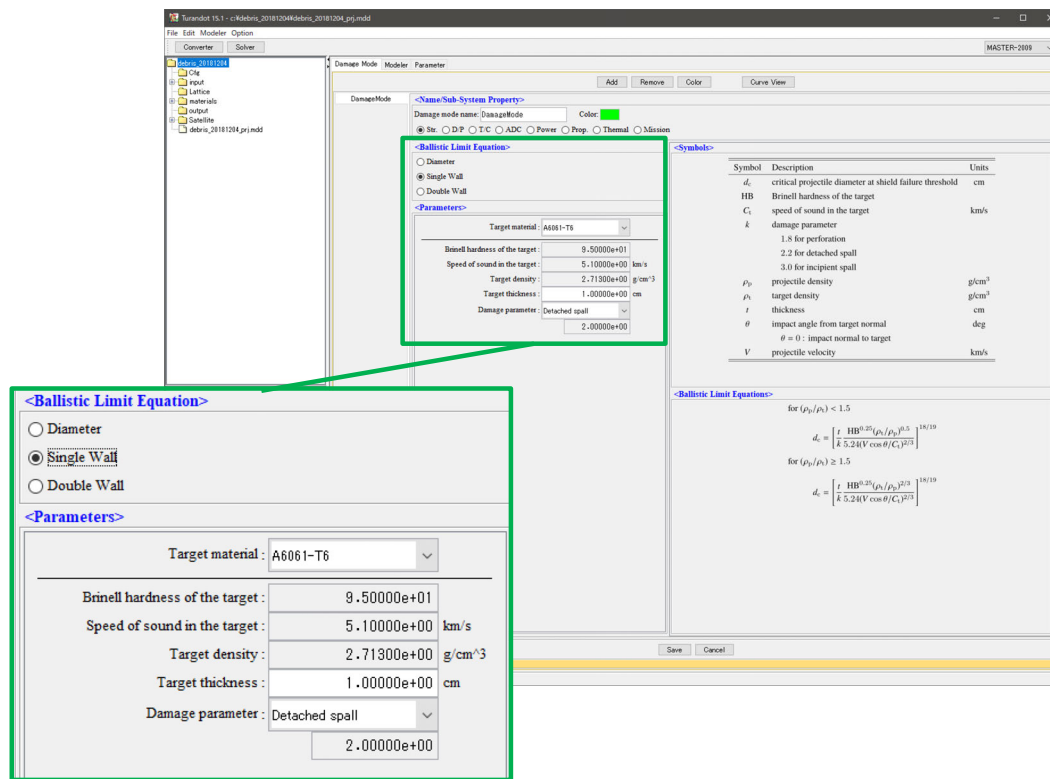
TURANDOT GUI Damage Mode : Diameter



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TURANDOT GUI

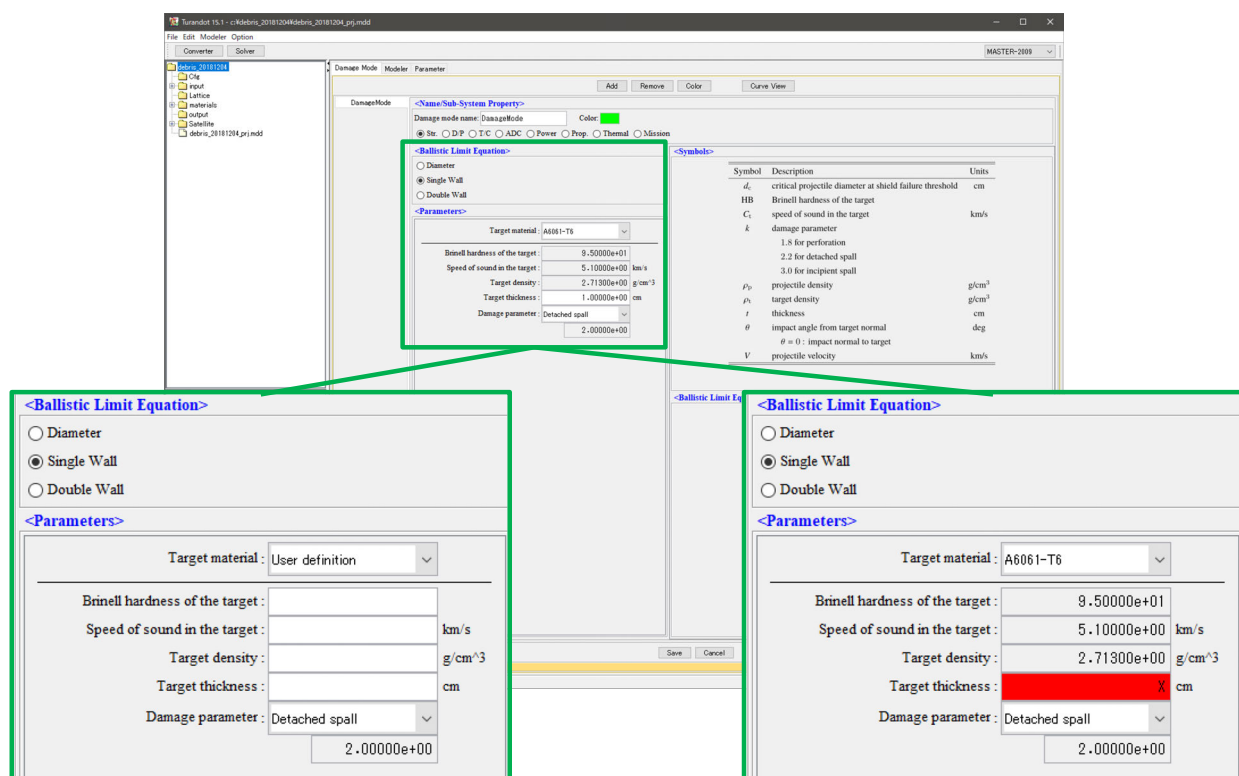
Damage Mode : Single Wall



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TURANDOT GUI

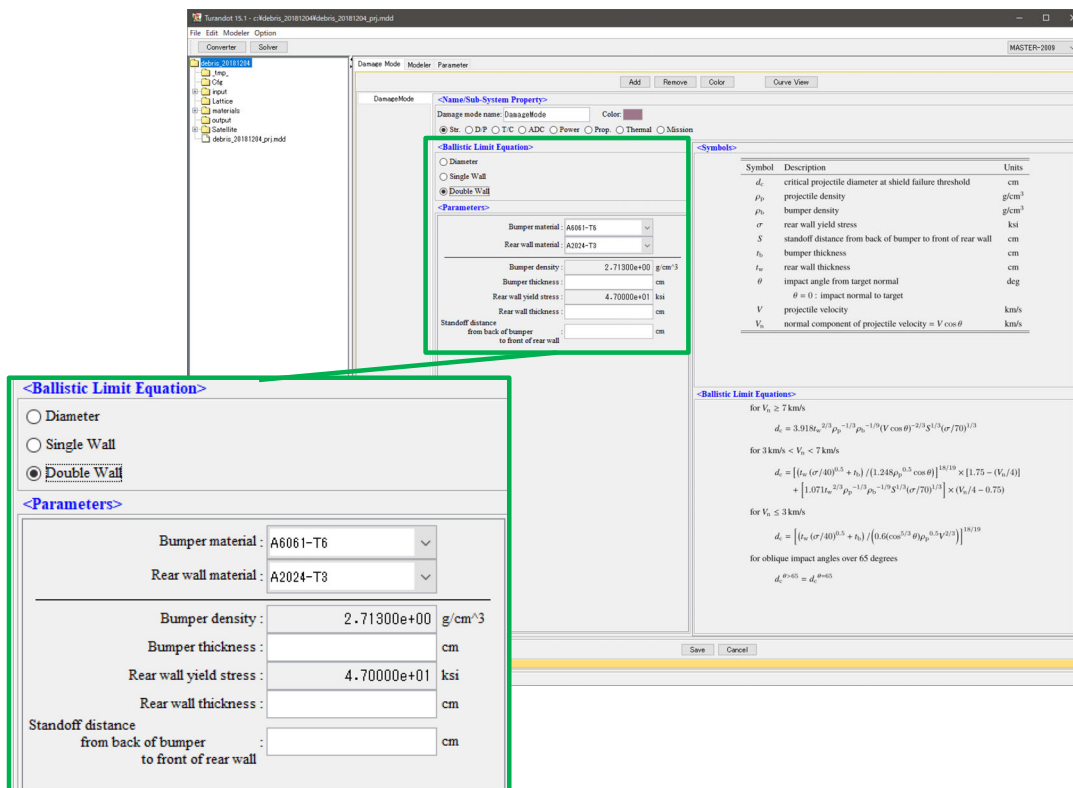
Damage Mode : Single Wall



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TURANDOT GUI

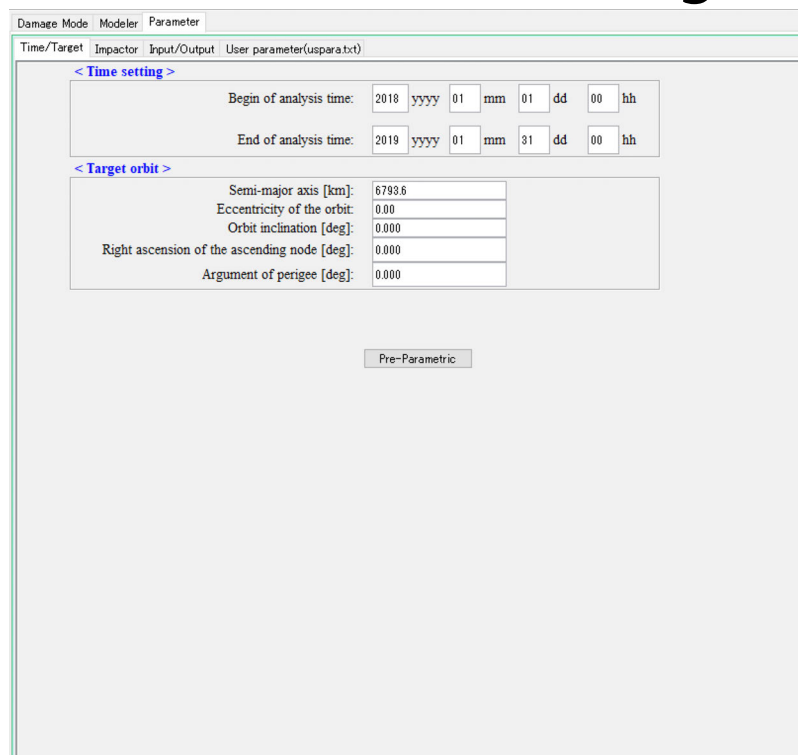
Damage Mode : Double Wall



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TURANDOT GUI

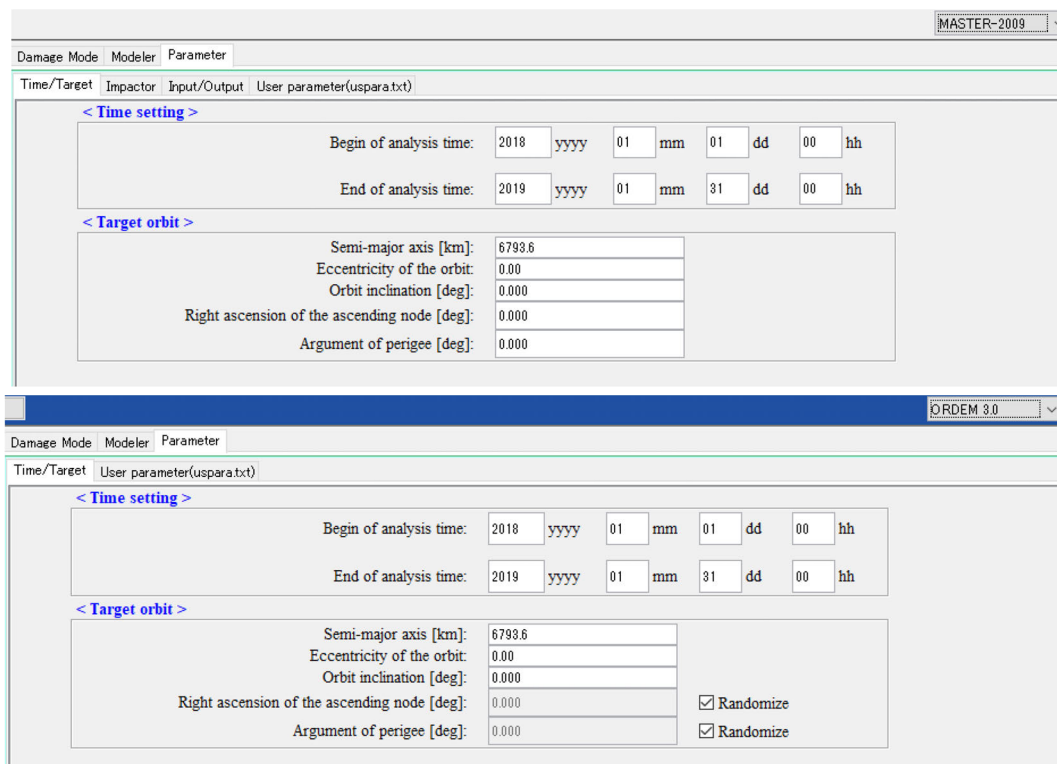
Parameter : Time/Target



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TURANDOT GUI

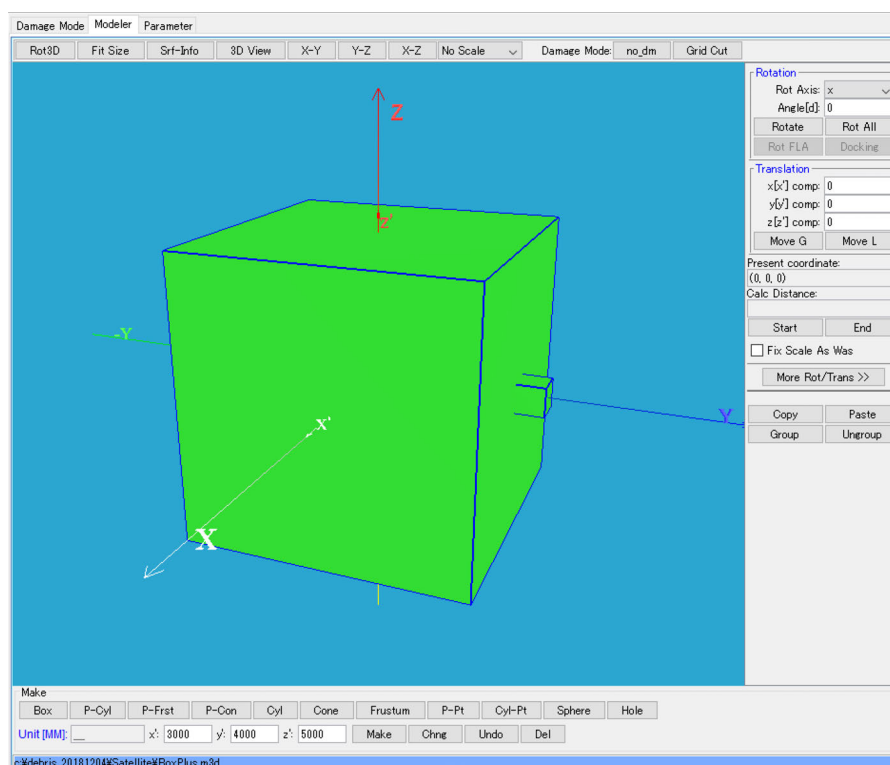
Sharing analysis conditions



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TURANDOT GUI

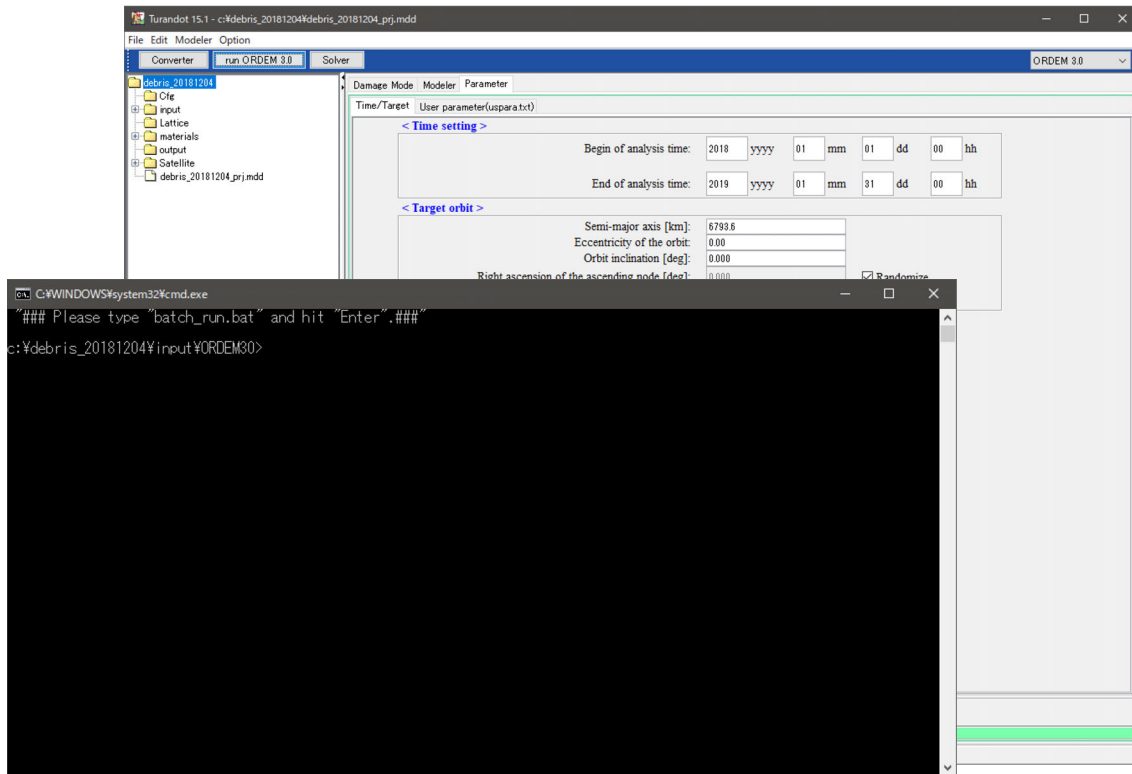
Modeler



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TURANDOT GUI

run ORDEM 3.0



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ORDEM 3.0

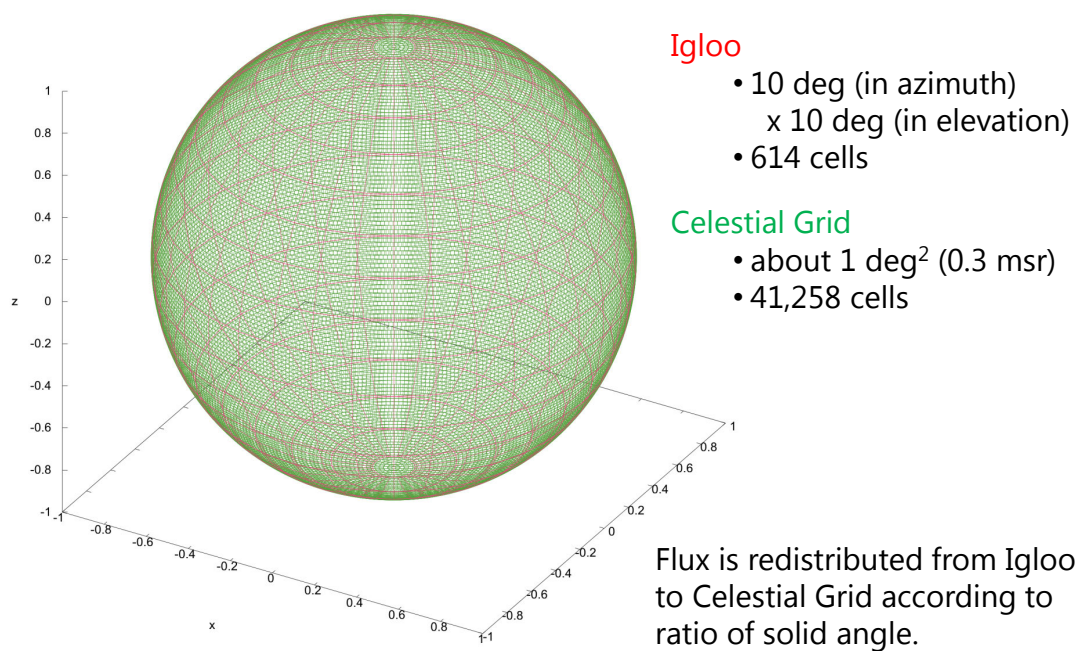
Table 2-1: Feature Comparison of ORDEM 2.0 and ORDEM 3.0

Parameter	ORDEM 2.0	ORDEM 3.0
Spacecraft & Telescope/Radar analysis modes	Yes	Yes
Time range	1991 to 2030	2010 to 2035
Altitude range with minimum debris size (LEO)	200 to 2000 km (>10 μm)	100 to 40,000 km (>10 μm)* (LEO to GTO) 34,000 to 40,000 km (>10 cm) (GEO)
Orbit types	Circular (radial velocity ignored)	Circular to highly elliptical
Model population breakdown by type & material density	No	Intacts Low-density (1.4 g/cc) fragments Medium-density (2.8 g/cc) fragments & microdebris High-density (7.9 g/cc) fragments & microdebris RORSAT NaK coolant droplets (0.9 g/cc)
Model cumulative size thresholds (fiducial points)	10 μm , 100 μm , 1 mm, 1 cm, 10 cm, 1 m	10 μm , 31.6 μm , 100 μm , 316 μm , 1 mm, 3.16 mm, 1 cm, 3.16 cm, 10 cm, 31.6 cm, 1 m
Flux uncertainties	No	Yes
Total input file size	13.5 MB	1.25 GB
Meteoroids	No	No**

NASA Orbital Debris Engineering Model ORDEM 3.0 - User's Guide, NASA/TP-2014-217370, p.5

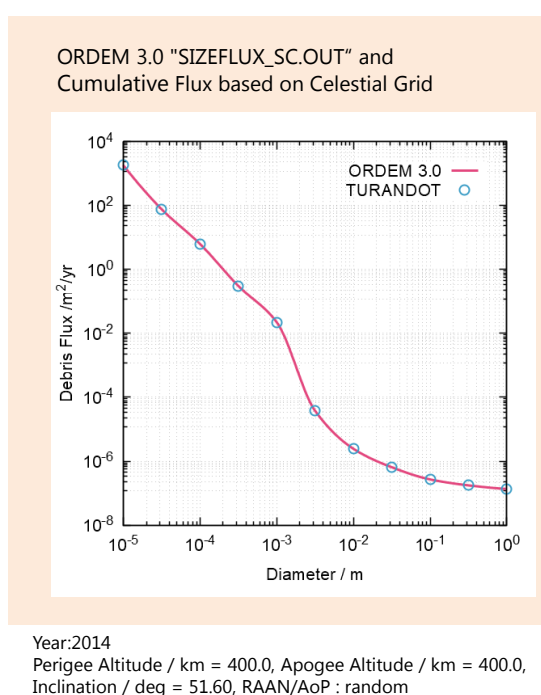
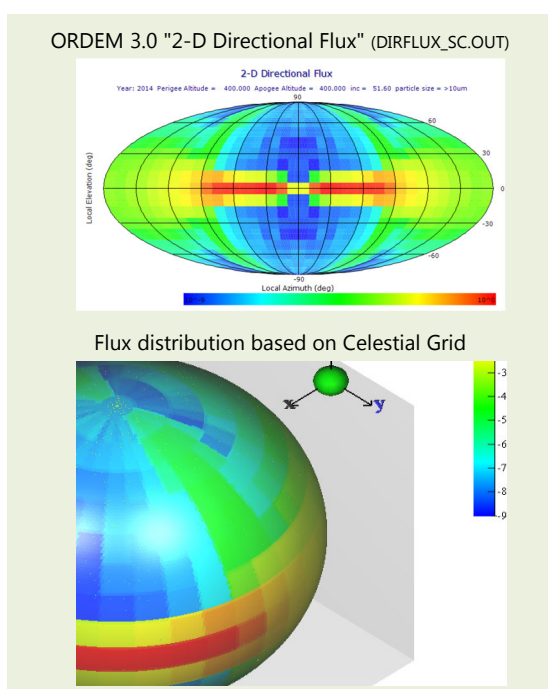
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Igloo and Celestial Grid



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Redistributed flux Igloo to Celestial Grid



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Conclusion

- An overview of TURANDOT was presented.
- TURANDOT is a user-friendly tool of M/OD risk assessment.