ESA's dark and quiet skies requirements and technology developments

Space Debris Office

10/12/2025

ESA Space Debris Mitigation Requirements

1. Policy

Who?

ESA space systems, operations under ESA's responsibility, contribution to international activities, procurement of launch services

2. Requirements: dark and quiet skies

What?

- Reduce brightness
- Quantify brightness
- Distribute data

3. Compliance Verification Guidelines

How?

- Guidelines on suitable methodologies for verification
- Indication of what's expected at the different mission phases

https://sdup.esoc.esa.int/documents/

Reduce Brightness

The developer and operator of a constellation in near Earth orbit shall propose and implement design and operational mitigation actions to reduce the visual brightness of the spacecraft.

Discussion:

- No limit specified → Seed requirement (IAU CPS recommendation added as note)

- What is a good requirement?
  - Peak brightness level
  - Percentage threshold
  - Rate of bright flares
  - Location/latitude dependency

Quantify Brightness

The developer of a spacecraft or launch vehicle orbital element in near Earth orbit shall quantify the visual brightness of the design.

Discussion:

- Software / lab / ground-based
- Dependency on attitude and observation geometry
- Uncertainties in modelling (optical properties database, degradation)

→ Verification with DRAMA 4.1.1 in following slides

Distribute Data

The developer and operator of a spacecraft or launch vehicle orbital element operating in near Earth orbit shall make available data on demand to support mitigation of impacts on astronomy, including brightness data, antenna diagrams, orbital profiles, and predicted and real-time orbital elements.

Discussion:

- Some data already shared for space traffic coordination,
  Brightness estimate available from quantification requirement (previous slide)

- Antenna diagrams could be difficult to obtain

ITU Radio Regulations

The developer and operator of a spacecraft or launch vehicle orbital stage operating in near Earth orbit shall protect the Radio Astronomy Service, in compliance with the ITU Radio Regulations and in compliance with requirements from clause 4 to clause 9 of ECSS-E-ST-50-05.

Discussion:

- ITU Regulation considered sufficient?
- Assessment of aggregated effect of constellations

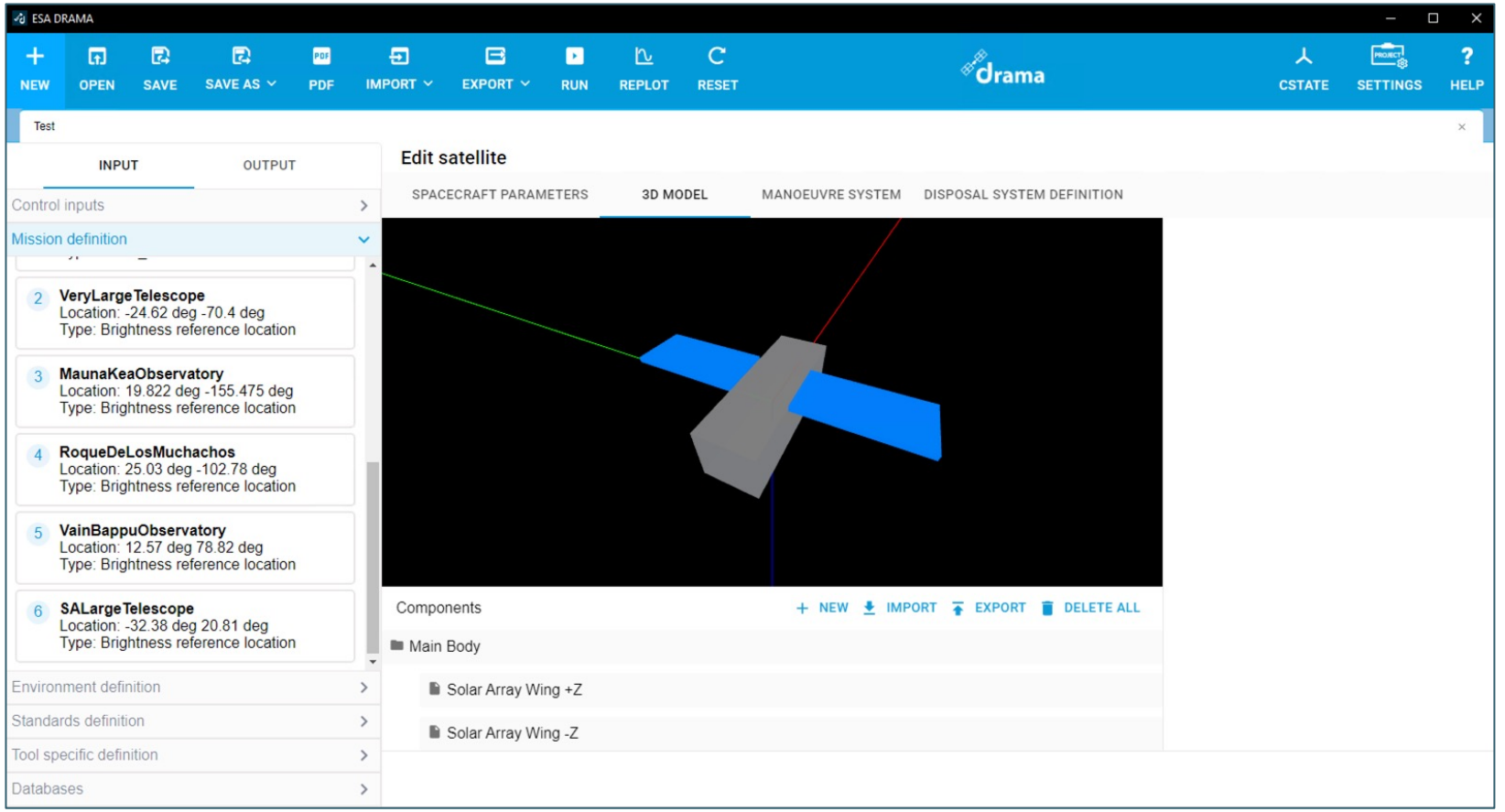
→ Verification approach improved with research activities presented in next slides

Compliance Verification: DRAMA 4.1.1

- Digital engineering tool
- Compatibility with latest space debris mitigation standards

- GUI
- Mission-centric view

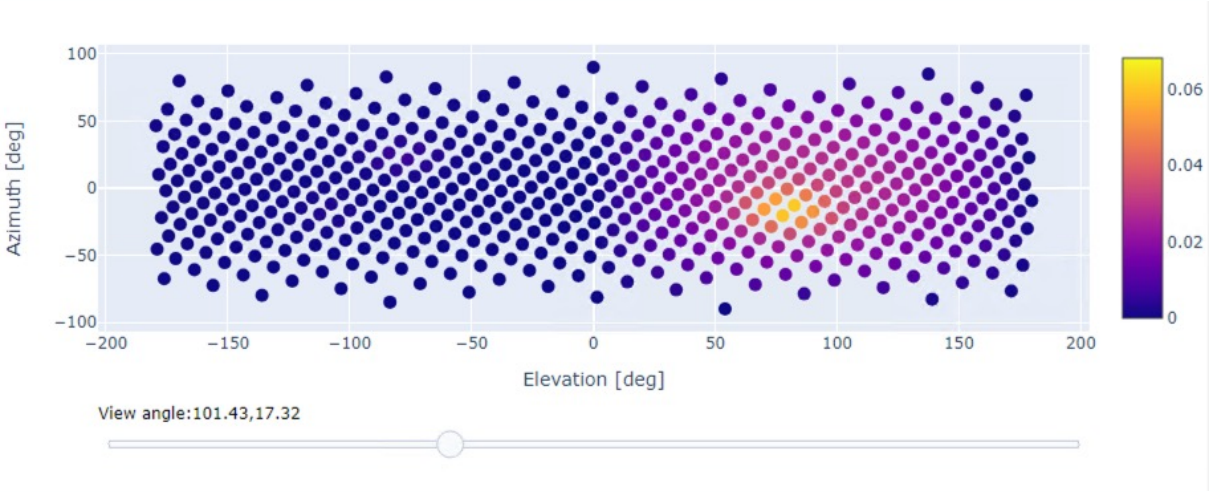
- Trackability assessment
- Brightness estimation
- Attitude and shape effects

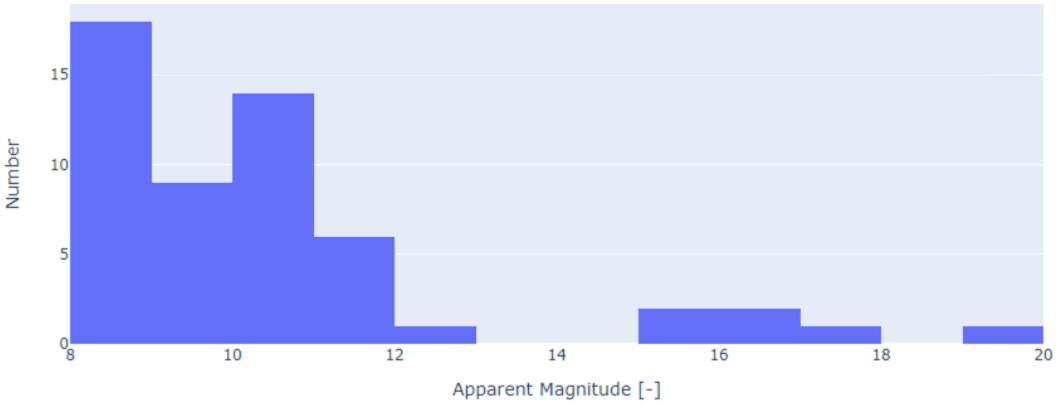


https://sdup.esoc.esa.int/drama

DRAMA 4.1.1: Outputs

- Coefficient look-up table:
  (allows computing apparent brighness for given geometry and distance)
- Magnitude histogramm for different observatories
- Crossing and brightness prediction





https://sdup.esoc.esa.int/drama

DRAMA 4.1.1: Material database

- Database shipped with software
  - Limited set of materials and preliminary material properties (will be updated)

Current model:

- Phong: combination of Lambert diffuse and empirical specular reflection model

- Material properties:
  - Diffuse reflection coefficient
  - Specular reflection coefficient
  - “Shininess constant”

FLARES Lab - Sapienza

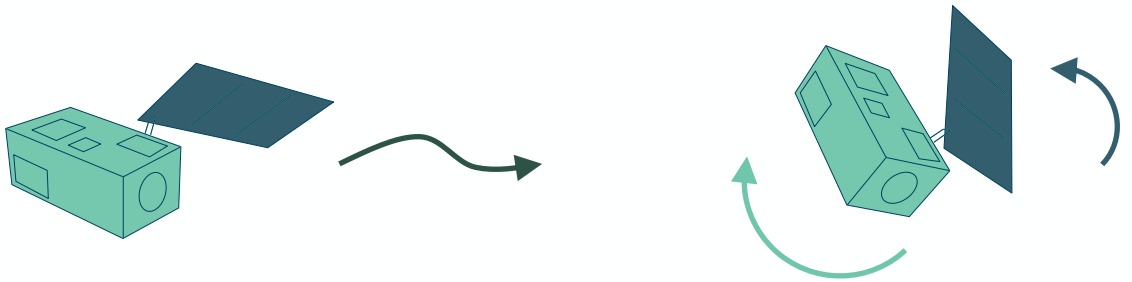
(Cimino et al, 2025)

https://sdup.esoc.esa.int/drama

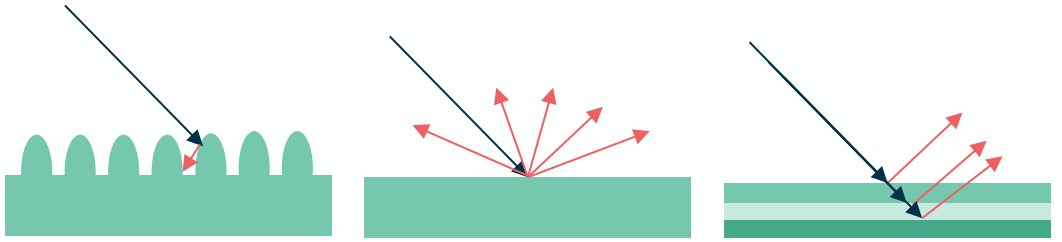
Technology Development (TDE) activities (Q1/2026)

Future update of DRAMA with new functionalities

- Impact of operation modes
  Estimate:
  - slewing efforts for a scenario to avoid bright flares
  - power losses
  - boresight avoidance - data gaps statistics
  - impact on radio quiet zones



- Coatings and materials



- Simulation of unintended emissions by satellites

Other future development outlined in Zero Debris Booklet → Presentation by Siegfried Eggl

Thank you for your attention!

Questions?

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