OKAPI ORBITS

# Making NewSpace Safer

## Space Traffic Management

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15.01.2025

# Agenda

- Summary of recent DRAMA activities
  - ARES updates
  - OSCAR updates
  - MIDAS updates
  - SARA updates
- DRAMA Architecture Summary
- Introduction of Coefficient Estimator
- Introduction of PROOF
- DRAMA Workflow Updates
- Further DRAMA-4.1 updates

# Summary of recent DRAMA activities
# Existing Tools

With contributions by:

ARES:

- Support of attitude dependent cross-sectional areas i.e. no longer assuming spherical HBR.
- Electric Collision Avoidance Manoeuvre support for different transfer types.

OSCAR:

- 6-DOF propagation support.
- Variable protected region intersection support.
- New disposal option types including resonance based, elliptical and circular de-orbiting.

MIDAS:

- Surface definitions now support propagated attitude.

SARA:

- New glass material.
- Added support for the simulation of spherical and cylindrical tanks.

# Summary of recent DRAMA activities
## New Tools

With contributions by:

Coefficient Estimator:

- New software from the ground up.
- Generate mesh of 3D model and resulting databases.
- Databases required for 6DOF propagation in OSCAR.

PROOF - Program for Radar and Optical Observation Forecasting:

- Existing tool introduced in the year 2000.
- Extensively modified for new application of trackability analysis.
- Calculate the crossings of objects over sensors (in-orbit and on-ground).
- Simulate laser, optical and radar sensors detection probability.

drama 4.1

# DRAMA 4 Architecture Summary

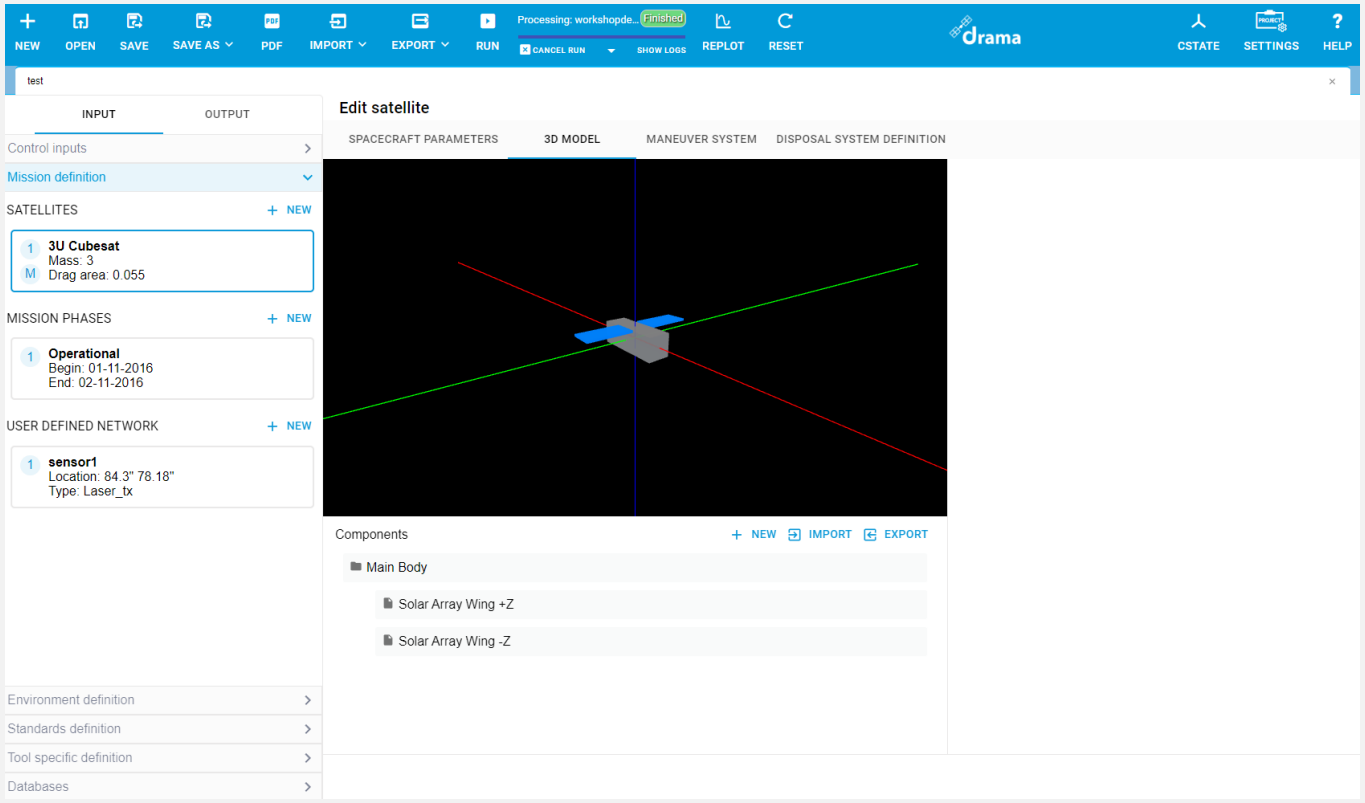
**Frontend**
- Allows for user inputs.
- Mission centric instead of tool centric.
- Sends request to backend server via REST API.
- Electron based

**Backend Server**
- Receives requests for analysis.
- Does the scheduling for all the workflows and tool processes.
- Python

**Workflow**
- Where the run mode is executed.
- Ensures all prerequisite tools and processes are executed e.g. determination of drag area.
- Python

**Wrapper**
- Tool specific python wrapper.
- Manages the inputs and outputs required by the tool.
- Executes process.
- Python

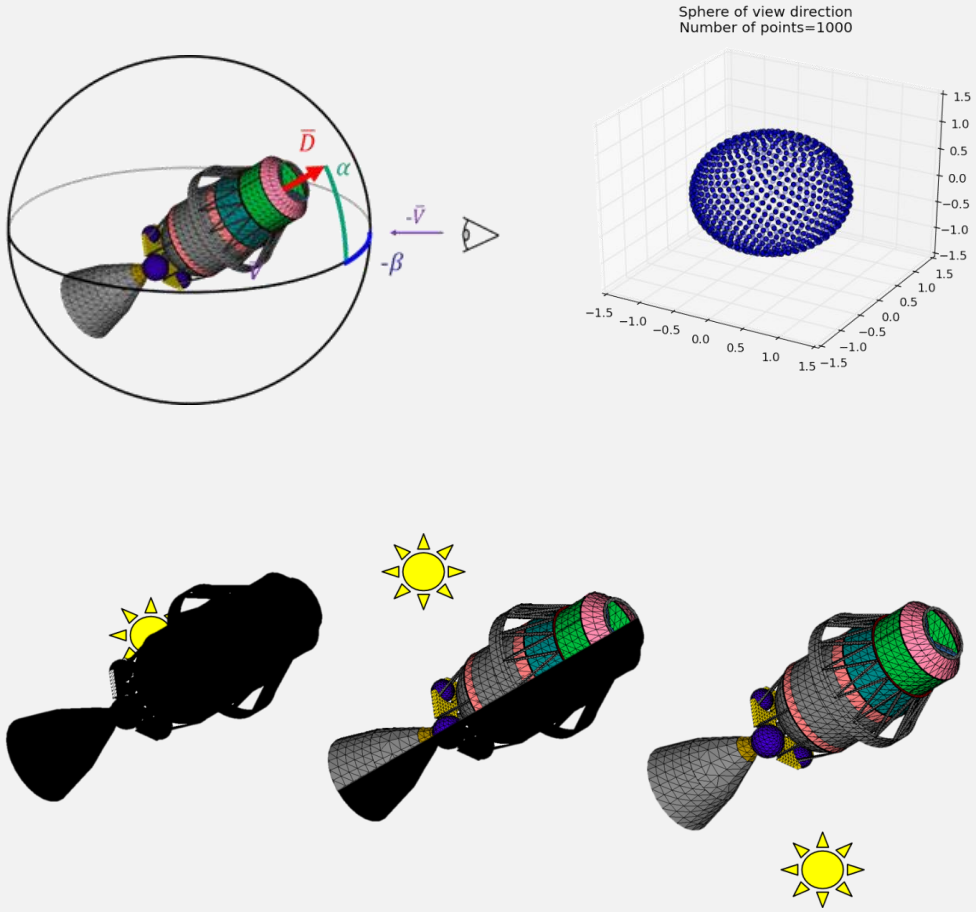
**Tool/ Process**
- Performs processing/analysis required.
- For example, ARES, OSCAR, PROOF etc.
- Tool specific language e.g. Fortran, C++, Java, Python etc.




Screenshot of DRAMA 4.1 GUI

# Coefficient Estimator Meshing

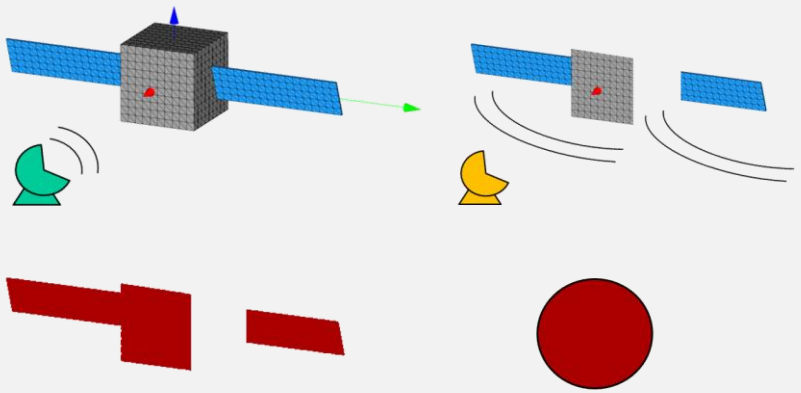
- Pre-computes in the database:
  - Optical cross-section,
  - Illumination,
  - Radar,
  - Retroreflector visibility.
- Provides attitude detection properties for complex geometries.
- Surface visibility and reflection properties considered.
- Observed intensity is equal to the solar intensity time illumination coefficient, divided by the inverse square law.



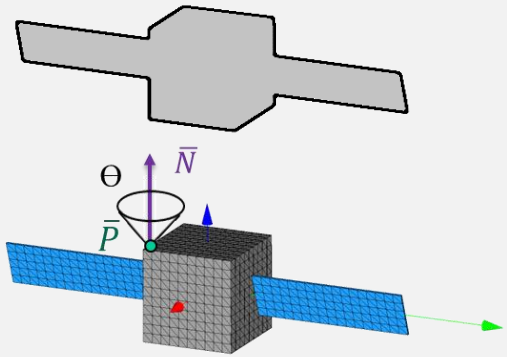

Visualisation of Coefficient Estimator functionality

# Coefficient Estimator Detection Properties

- The radar equivalent area is stored in the database
- The diameter of this radar equivalent area is then used as input for the NASA SEM



- The optical cross-section database contains the projected area.
- Can replace CROC for cross-section calculation → no longer requiring OpenGL.
- The retroreflector database contains which reflectors are visible from each of the view angles.

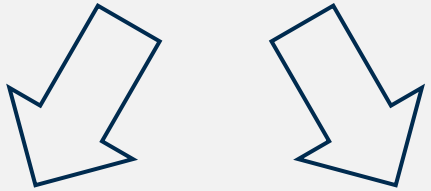



Visualisation of Coefficient Estimator functionality

# PROOF
# Origins and Updates

- Legacy use case was to provide statistical pass characteristic of space debris populations → validate MASTER population.

- For the new functionality it was split into two new executables:
    - Crossing which from object state vectors can determine sensor passes.
    - Detection which uses sensor performance modelling to determine whether the object can be detected.

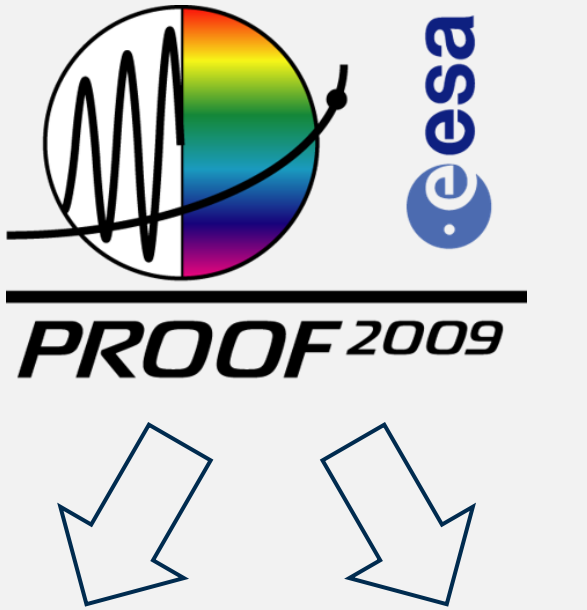



PROOF Crossing

PROOF Detection

# PROOF
# Origins and Updates

- New functionality and changes also include:
    - Support for sensor networks instead of single sensors including both ground and space-based sensors
    - Laser ranging simulation.
    - Accept object state vectors instead of internal SGP4 propagation.
    - Automatic tracking instead of passive observations.
    - Light pollution simulation.
    - Extensive refactoring of certain packages.

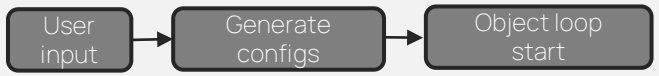


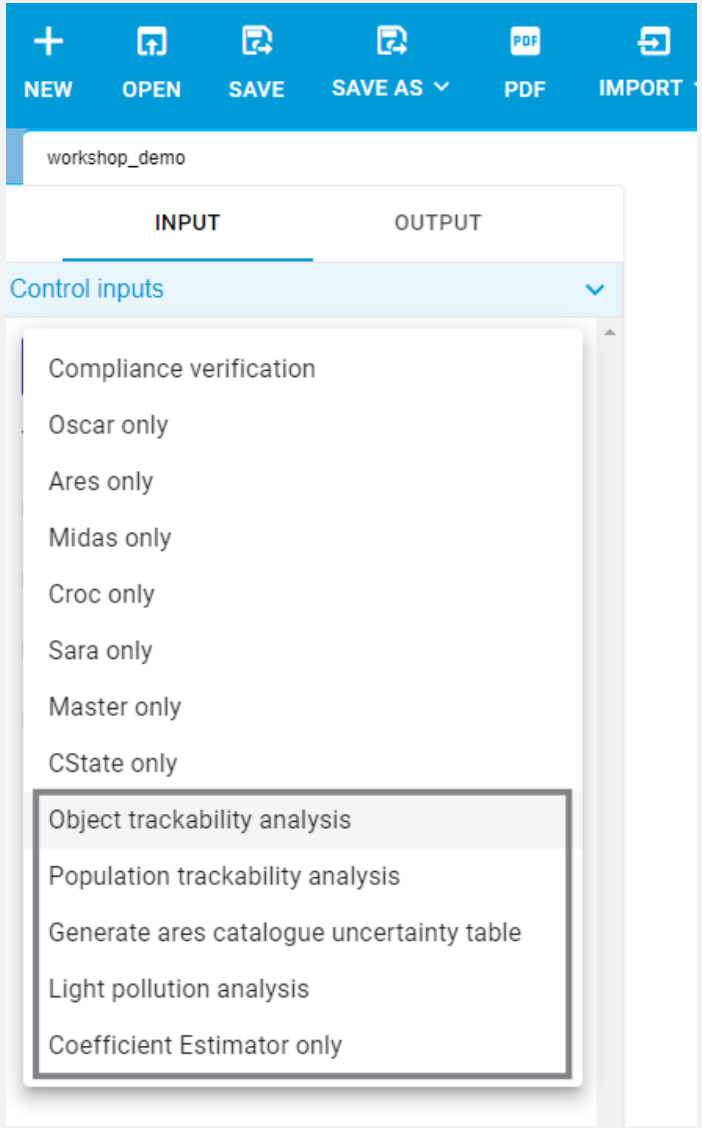

PROOF Crossing

PROOF Detection

# DRAMA Workflow Update
# New Run Modes

- Objective was to support mission designers in detectability and trackability guidelines verification.
- 4 new run modes:
  - Object trackability
  - Light pollution analysis
  - Population trackability analysis
  - Generate ARES uncertainty tables
- All run modes use the new extendedProofWorkflow, starting with the following.
- Start of the workflow:




Screenshot of DRAMA 4.1 Run Mode selection

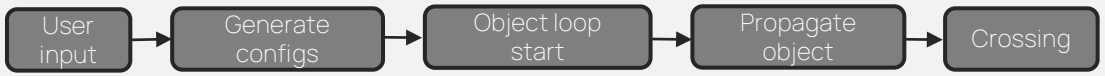
# DRAMA Workflow Update

## Propagation

- NEPTUNE - NPI Ephemeris Propagation Tool with Uncertainty Extrapolation, was also integrated into the DRAMA framework.
- Same integration as with all other DRAMA tools: executable → python wrapper → workflow.
- Object is propagated for a user-defined duration equivalent to the orbit determination fit span.

# DRAMA Workflow Update
# PROOF Crossing

- PROOF crossing used to determine sensor network crossings.
- Crossings are interpolated to generate 24-time steps.
- Important vectors are provided for later processing:
  - Object state vector
  - Object→sensor vector
  - Object→transmitter vector (bi-static sensors)
  - Object→sun vector (telescopes)

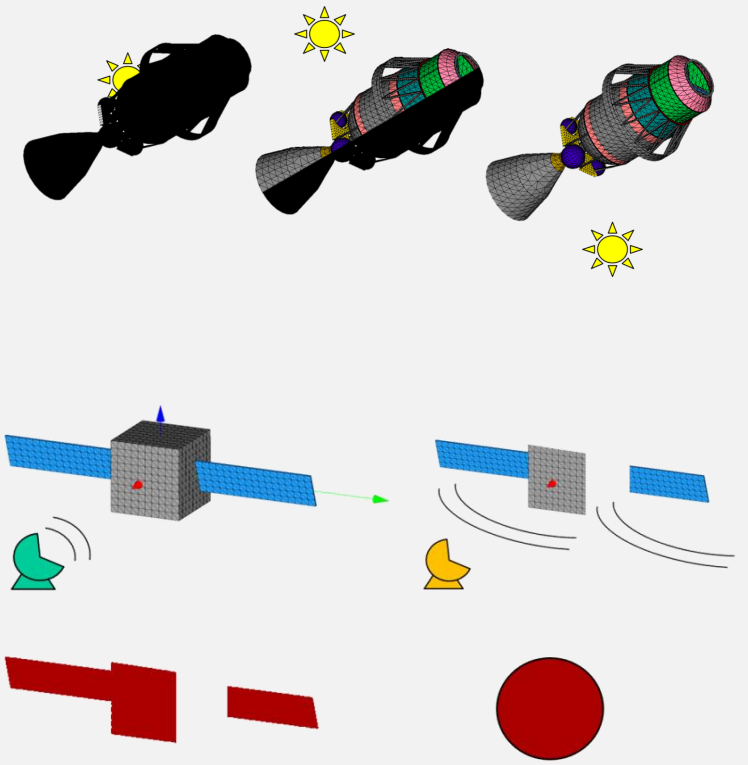



```
# ------------------------------------------------------------------
# ECI RESULTS SETTINGS:
# ------------------------------------------------------------------
# 07) Epochs
#       YYYY-MM-DD HH:MM:SS.sss
# 08) Epochs
#       MJD
# 09) X                                                  [km]
# 10) Y                                                  [km]
# 11) Z                                                  [km]
# 12) X_DOT                                             [km/s]
# 13) Y_DOT                                             [km/s]
# 14) Z_DOT                                             [km/s]
# 15) Object-Sensor Vector X-component                   [km]
# 16) Object-Sensor Vector Y-component                   [km]
# 17) Object-Sensor Vector Z-component                   [km]
# 18) X-component
# 19) Y-component
# 20) Z-component
#       Object-Transmitter (bi-static)                   [km]
#       Object-Sun         (telescope)                   [AU]
#       not used           (mono-static)                  [-]
#
# ----------------------------------------|-----------------------------------------------------------------------------------------|--------------------
# EPOCH                                   | OBJECT STATE                                                                            | ADDITIONAL VECTORS
# ----------------------------------------|-----------------------------------------------------------------------------------------|--------------------
# 07)                       08)           | 09)          10)          11)          12)          13)          14)                     | 15)                16)
# ----------------------------------------|-----------------------------------------------------------------------------------------|--------------------
   2018-05-01 12:17:48.462   58239.512366458    -2078.179367     802.093809    6212.018390     7.353237     0.859854     2.350148     1268.523130
   2018-05-01 12:18:02.765   58239.512531999    -1972.719617     814.278318    6244.751174     7.393204     0.843906     2.226871     1161.988164
   2018-05-01 12:18:17.067   58239.512697540    -1866.703137     826.233007    6275.716141     7.431080     0.827721     2.102974     1054.897350
   2018-05-01 12:18:31.370   58239.512863081    -1760.159918     837.954543    6304.904816     7.466858     0.811303     1.978490      947.280681
   2018-05-01 12:18:45.673   58239.513028623    -1653.120065     849.439635    6332.309077     7.500526     0.794658     1.853456      839.168261
   2018-05-01 12:18:59.976   58239.513194164    -1545.613813     860.685063    6357.921303     7.532075     0.777790     1.727906      730.590328
   2018-05-01 12:19:14.278   58239.513359705    -1437.671526     871.687671    6381.734372     7.561497     0.760704     1.601875      621.577246
   2018-05-01 12:19:28.581   58239.513525246    -1329.323682     882.444370    6403.741665     7.588784     0.743405     1.475400      512.159495
   2018-05-01 12:19:42.884   58239.513690787    -1220.600872     892.952144    6423.937068     7.613929     0.725896     1.348515      402.367667
   2018-05-01 12:19:57.187   58239.513856328    -1111.533783     903.208041    6442.314974     7.636925     0.708185     1.221257      292.232451
   2018-05-01 12:20:11.489   58239.514021869    -1002.153183     913.209164    6458.870138     7.657766     0.690274     1.093660      181.784614
   2018-05-01 12:20:25.792   58239.514187410     -892.489950     922.952723    6473.598094     7.676446     0.672170     0.965761       71.055037
   2018-05-01 12:20:40.095   58239.514352951     -782.575030     932.435990    6486.494816     7.692959     0.653877     0.837596      -39.925334
   2018-05-01 12:20:54.398   58239.514518492     -672.439432     941.656305    6497.556754     7.707303     0.635401     0.709200     -151.125488
   2018-05-01 12:21:08.700   58239.514684033     -562.114225     950.611080    6506.780870     7.719473     0.616746     0.580609     -262.514355
   2018-05-01 12:21:23.003   58239.514849574     -451.630526     959.297805    6514.164637     7.729465     0.597918     0.451860     -374.060818
   2018-05-01 12:21:37.306   58239.515015115     -341.019494     967.714039    6519.706041     7.737278     0.578923     0.322988     -485.733715
```

Screenshot of Proof Crossing output

# DRAMA Workflow Update
# Coefficient Estimator

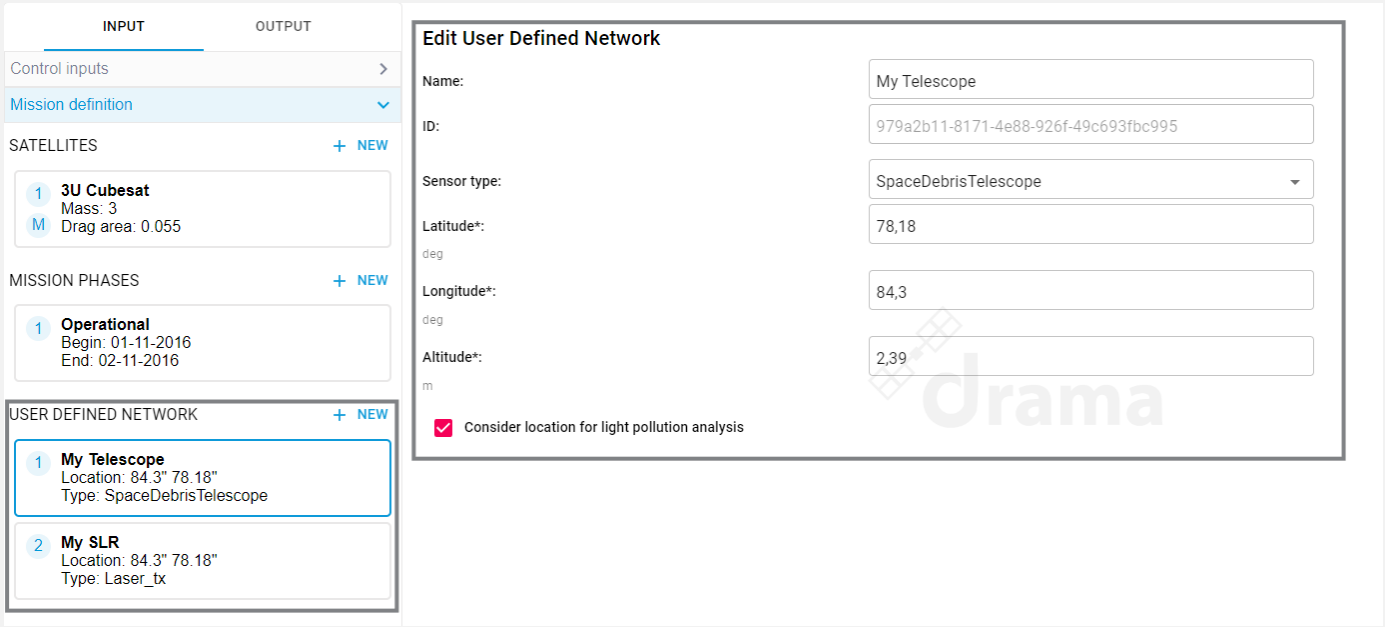
- If a population is being analysed, the coefficient estimator will not be called and predefined detection properties will be used.
- Coefficient Estimator will:
  - Generate databases, if they haven't been already.
  - Determine retroreflector visibility (Boolean).
  - Determine illumination coefficient.
  - Determine radar and optical cross-section .
- All these values are tabulated and not assumed constant.



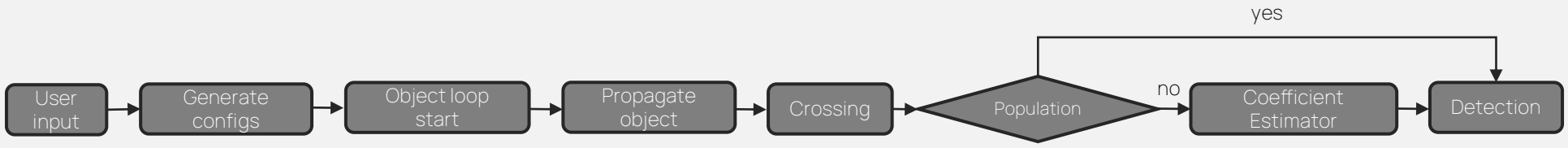
Visualisation of Coefficient Estimator functionality

# DRAMA Workflow Update
# PROOF Detection

- Use of the PROOF detection software to determine whether crossing would result in a detection.
- Ability for the user to select their own network of sensors.
- Possibility to select preconfigured networks such as US-SSN.
- Detection process then returns tracklets that were detected.

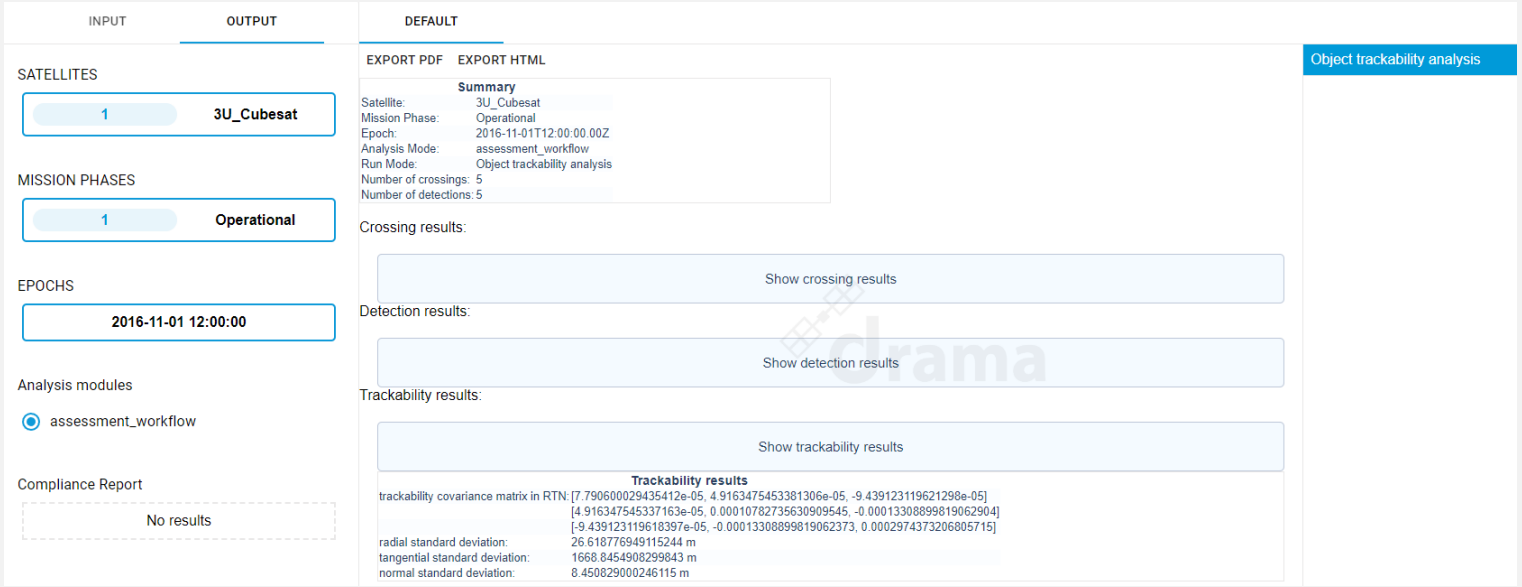



Screenshot of DRAMA 4.1 User defined network settings

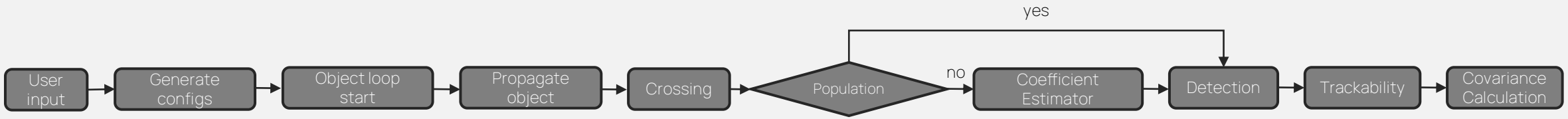


# DRAMA Workflow Update
# Covariance Determination

- Differential correction method based on linear least squared is used to determine the resulting “initial OD” covariance.
- Bias and noise of the observing sensors is used.
- Resulting covariance is propagated to user-specified duration.

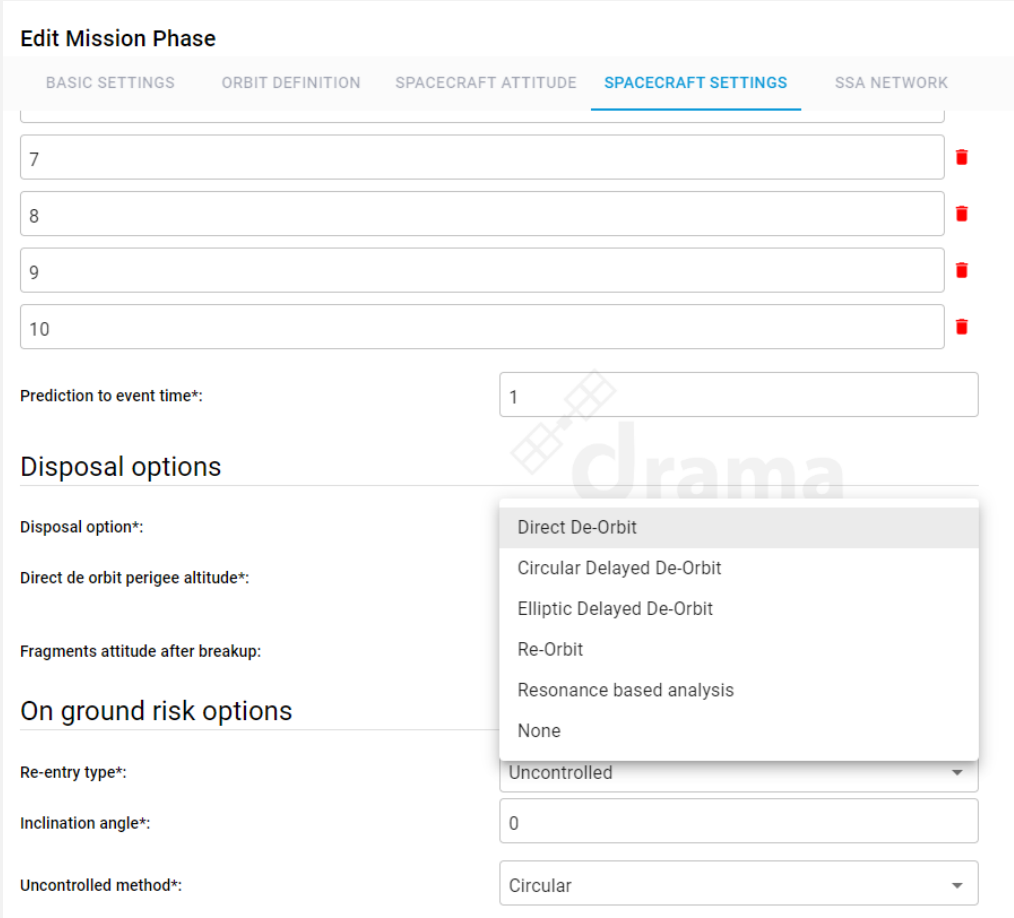



Screenshot of DRAMA 4.1 results of object trackability run mode



# Further DRAMA 4.1 updates OSCAR

- New functionality was integrated into the GUI:
  - Protected regions are synced with ESA server.
  - New disposal opens.
  - Renaming of drag tether.
- 6DOF propagation was integrated into MIDAS and ARES workflows.
- Coefficient estimator integration for drag area calculation and 6DOF integration.




Screenshot of DRAMA 4.1 showing new disposal options

# Further DRAMA 4.1 updates

## ARES

- ARES can now account for different cross-sections from different impact directions for different time-steps.
- The ARES specific workflow has been updated.
- Initialise 6DOF attitude propagation from OSCAR and the Coefficient Estimator to generate the ares.css file.

```
# =====<ESA/DRAMA>=============================================================================================
#
#      _/_/_/    _/_/_/    _/_/              _/_/_/    _/_/_/      _/_/    _/      _/    _/_/
#     _/    _/  _/    _/  _/  _/            _/    _/  _/    _/  _/    _/  _/_/  _/_/  _/    _/
#    _/_/_/    _/_/_/    _/_/_/_/ _/_/_/_/ _/    _/ _/_/_/    _/_/_/_/ _/  _/  _/ _/  _/_/_/_/
#   _/    _/  _/    _/  _/    _/           _/    _/ _/    _/  _/    _/ _/      _/ _/  _/    _/
#  _/_/_/    _/    _/  _/    _/            _/_/_/  _/    _/  _/    _/ _/      _/ _/  _/    _/
#
# =============================================================================================================
#                     ESA Debris Risk Assessment and Mitigation Analysis Tool
#                               Assessment of Risk Events Statistics
#-------------------------------------------------------------------------------------------------------------
#                                          DRAMA  - ARES
#-------------------------------------------------------------------------------------------------------------
#                               ARES cross-section ephemerides file
#-------------------------------------------------------------------------------------------------------------
# ares.css specifies the cross-section exposed by the target spacecraft towards the
# different impact directions for different time steps.
#
# If the cross-section ephemerides file switch is set to 1 in ares.inp, this file
# will be looked for in the path given in ares.cfg
#-------------------------------------------------------------------------------------------------------------
# This is an example file for constant cross section equal to that of the default spacecraft
# in ares.inp (which has a radius of 0.05m)
#-------------------------------------------------------------------------------------------------------------
# Time (MJD1950.0)     Imact azimuth(º)     Impact elevation(º)   Cross-section(m^2)
#-------------------------------------------------------------------------------------------------------------
25000.000000000000    -160.000000000000     -72.000000000000       0.007853981634
25000.000000000000    -160.000000000000     -36.000000000000       0.007853981634
25000.000000000000    -160.000000000000       0.000000000000       0.007853981634
25000.000000000000    -160.000000000000      36.000000000000       0.007853981634
25000.000000000000    -160.000000000000      72.000000000000       0.007853981634
25000.000000000000    -120.000000000000     -72.000000000000       0.007853981634
25000.000000000000    -120.000000000000     -36.000000000000       0.007853981634
25000.000000000000    -120.000000000000       0.000000000000       0.007853981634
25000.000000000000    -120.000000000000      36.000000000000       0.007853981634
25000.000000000000    -120.000000000000      72.000000000000       0.007853981634
25000.000000000000     -80.000000000000     -72.000000000000       0.007853981634
```

Screenshot of new ARES cross-section ephemerides (ares.css) file

# Further DRAMA 4.1 updates MIDAS

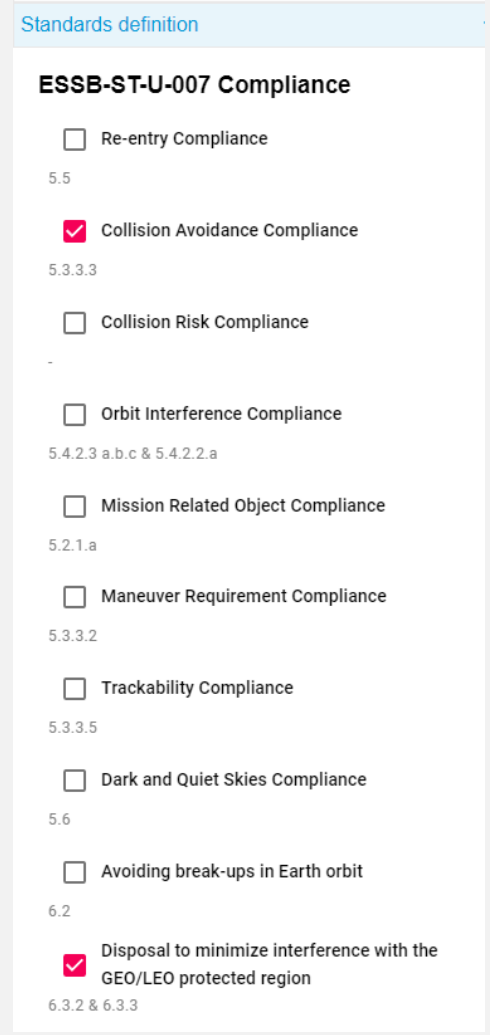
- Wrapper now calculates failure (penetration) probability of each/all surfaces.
- MIDAS supports epoch specific surface attitude information.
- MIDAS workflow initialises 6DOF attitude propagation and calculates the surface file(s).

```
# =====<ESA/DRAMA>=============================================================================================
#
#     _/_/_/   _/_/_   _/_/            _/_/_   _/_/_    _/_/   _/    _/   _/_/
#    _/       _/      _/  _/          _/   _/ _/   _/ _/  _/ _/_/ _/_/ _/ _/  _/
#   _/_/_    _/_/   _/_/_/_ _/_/_/_ _/   _/ _/_/_/  _/_/_/_ _/ _/ _/ _/_/_/_
#  _/       _/  _/ _/   _/          _/   _/ _/   _/ _/   _/ _/    _/ _/   _/
# _/_/_/_ _/_/_/  _/   _/           _/_/_/  _/   _/ _/   _/ _/    _/ _/   _/
#
# =============================================================================================================
#
# MIDAS (MASTER-based Impact Flux and Damage Assessment Software) Attitude Ephemeris File
# [v3.2.0, 03/2022]
#
#=============================================================================
#
# Attitude Ephemeris
#
#-------------------------------------:-------------------------------------
#
#  Epoch as ISO8601 string (CHAR*26)
#
#  A - Azimuth / Right ascension
#                     -180 deg < A < 180 deg :  azimuth of surface normal for Earth-oriented
#                     -180 deg < A < 180 deg :  right asc. deviation from sun LOS for Sun-oriented
#                     -180 deg < A < 180 deg :  right asc. of surface normal for inertially fixed
#  h - Elevation / declination
#                     -90 deg < h < 90 deg  :  elevation of surface normal for Earth-oriented
#                     -90 deg < h < 90 deg :  declination deviation from sun LOS for Sun-oriented
#                     -90 deg < h < 90 deg  :  declination of surface normal for inertially fixed
#
#-------------------------------------------------------------------------------------------------------------
#       Epoch / UTC             A / deg   h / deg
#-------------------------------------------------------------------------------------------------------------
2016-11-01T00:00:00.000000     0.0012      0.0146
2016-11-06T00:00:00.000000   179.5674      0.0234
#-------------------------------------------------------------------------------------------------------eof---
```

Screenshot of new ARES cross-section ephemerides (surface.att) file

# Further DRAMA 4.1 updates
# Compliance Updates

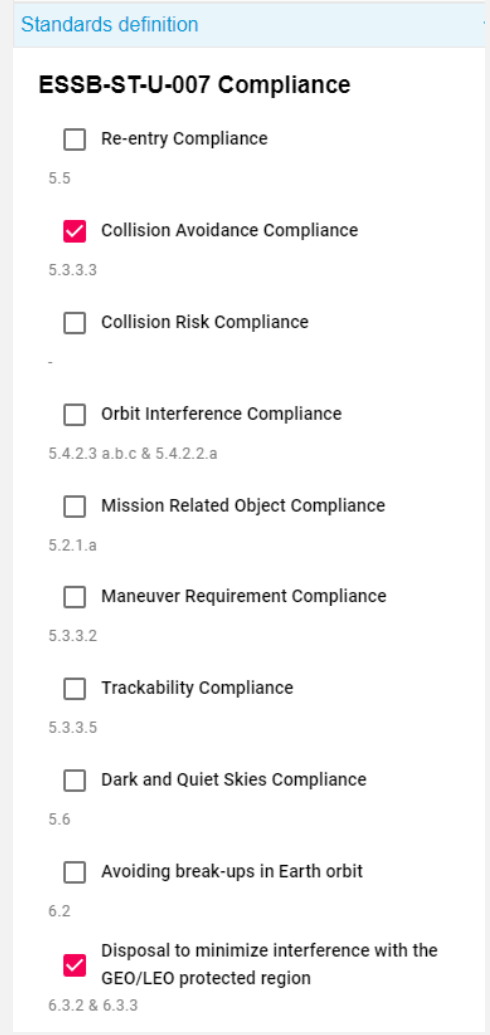
- Since DRAMA 4.0 development ESSB space debris mitigation standards have been updated.
- New compliance in accordance with ESSB-ST-U-007:
  - Re-entry compliance: which now accounts for the stricter fatality risks for constellations of >100 satellites.
  - Collision avoidance assess uses ARES to approximate a recommended ACPL that reduces collision risk by 90%.
  - Collision risk compliance: used to calculate collision risk with objects of different ranges (and in future, with manned spacecraft).
  - Orbit interference compliance: uses a 100-year OSCAR propagation and collision risk to assess LEO and GEO violations.




DRAMA 4.1 ESSB compliance selection

# Further DRAMA 4.1 updates
# Compliance Updates

- Orbit interference compliance: uses a 100-year OSCAR propagation and collision risk to assess LEO and GEO violations.
- Maneuver requirement compliance: determines whether a spacecraft mission requires maneuver capabilities.
- Trackability compliance: determines trackability of a mission in LEO and GEO and whether thresholds are met (100m and 1000m respectively).
- Dark and quiet skies compliance: performs a light pollution analysis and compares the results with IAU guidelines (brightness of magnitude 7.




DRAMA 4.1 ESSB compliance selection

# Commercial Mission Analysis Tool
## ESA - Market Study

- OKAPI:Orbits and ESA are conducting a market study for viability analysis of a commercial mission analysis tool.
- The survey is anonymous and takes about 5 minutes to complete.
- The goal is to understand the importance of sustainable mission design and the important key factors for the industry and academia.