Swiss SKA Days 2024
September 3 2024

EPFL Coordinates Research and Community Interests in Switzerland for the Protection of Dark and Quiet Skies

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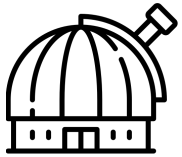
Why is Switzerland Concerned about Dark and Quiet Skies?

- **Switzerland joined SKAO in 2022**
- Swiss researchers are also involved in **CTAO**, **MeerKAT**, **MWA**, and **HIRAX**
- Several **Swiss industries** support large satellite constellations and would be **impacted by regulations**
- **EPFL** organizes meetings facilitate dialog between **Radio Astronomy**, **Space Sustainability**, and **Industry Stakeholders** and raise awareness for the Swiss delegation at UN COPOUS

Sustainable Space Hub

Increase awareness of the debris situation in near-Earth space, study environmental impacts and develop tools to identify technology gaps and support sustainable mission design.

Measure



Fill knowledge gaps about space activities

Understand

Analyse risks & environmental implications

Act

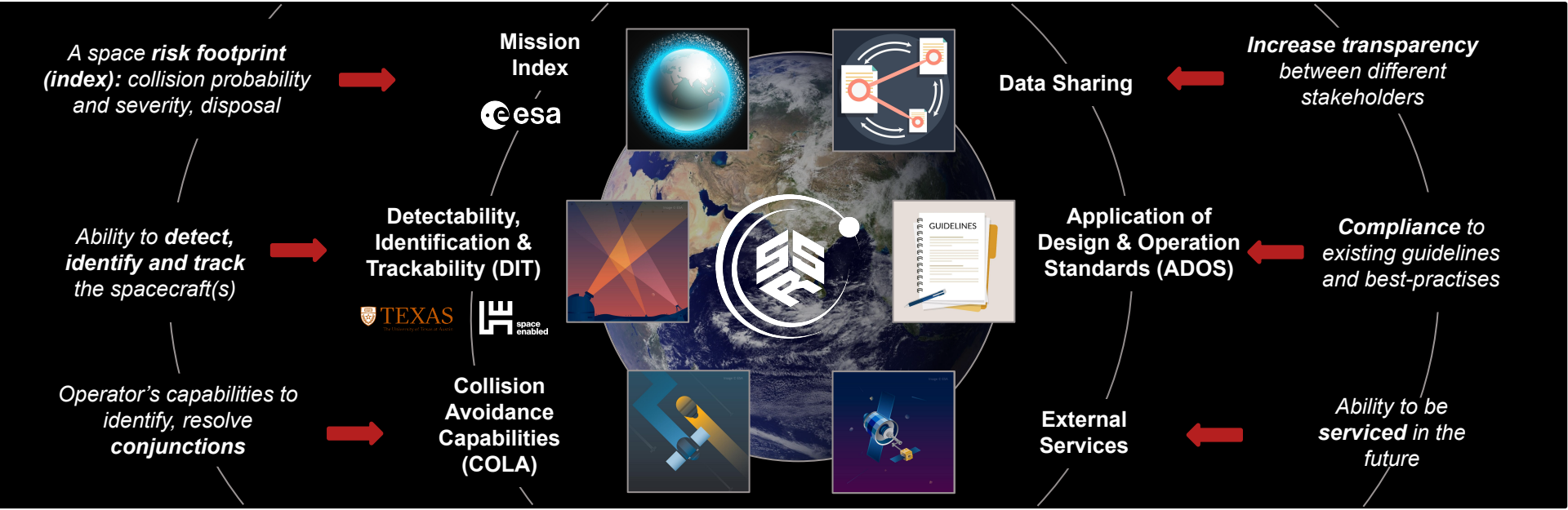
Assess mission design and policy making

A Dark and Quiet Skies Module for the Space Sustainability Rating

Space Sustainability Rating

Encouraging space actors to design & implement sustainable & responsible space missions for the long-term sustainability of the space environment

Overview the SSR Modules



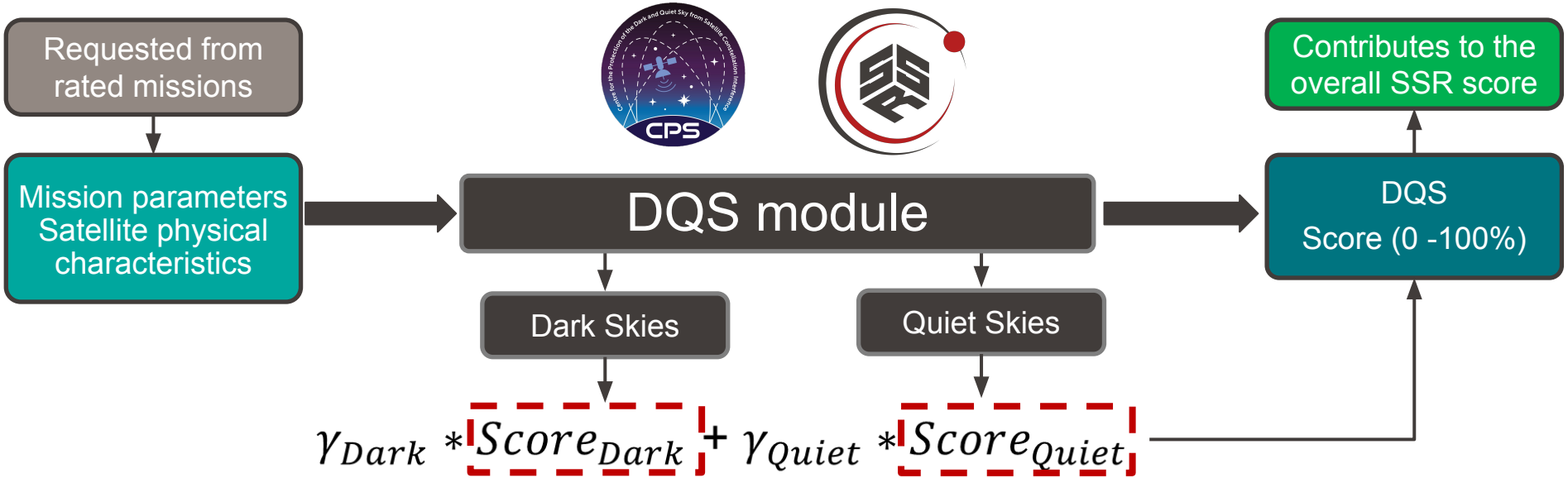
Letizia F. et. al. "Framework for the Space Sustainability Rating"

Development of a Dark and Quiet Skies module

Participating in the IAU CPS Policy Hub

- Phase I: July-August 2022
  - Internship: Literature review
- Phase II: September-December 2022
  - Semester projects: Preliminary module definition
- Phase III: February-June 2023
  - Semester Project and Master Thesis: Preliminary definition of module's sub-components (Dark Skies, Quiet Skies)
  - Milestone: IAU Symposium 385 "Astronomy and Satellite Constellations: Pathways Forward". 2-6 October 2023

Development of a Dark and Quiet Skies module



Adrien Saada: Towards the development of a Dark and Quiet Skies (DQS) Module for the SSR, IAU Symposium 385

Dark Skies: Scope and Formulation

- Take-on from the Detectability module
  - Enhance the existing framework (material database for albedo)
  - Define scoring function based on the existing visual magnitude framework
  - Study impact of key mission parameters on magnitude output

$$Score_{Dark} = \gamma_1 S_{Design} + \gamma_2 S_{Aggregated} + \gamma_3 S_{Questionnaire}$$

S_{Design} Impact at spacecraft level (i.e., apparent magnitude wise)

$S_{Aggregated}$ Aggregated impact at mission level (i.e., data-loss wise)

$S_{Questionnaire}$ Impact of other parameters (non-quantitative criteria that can be used in a compliance/non compliance questionnaire)

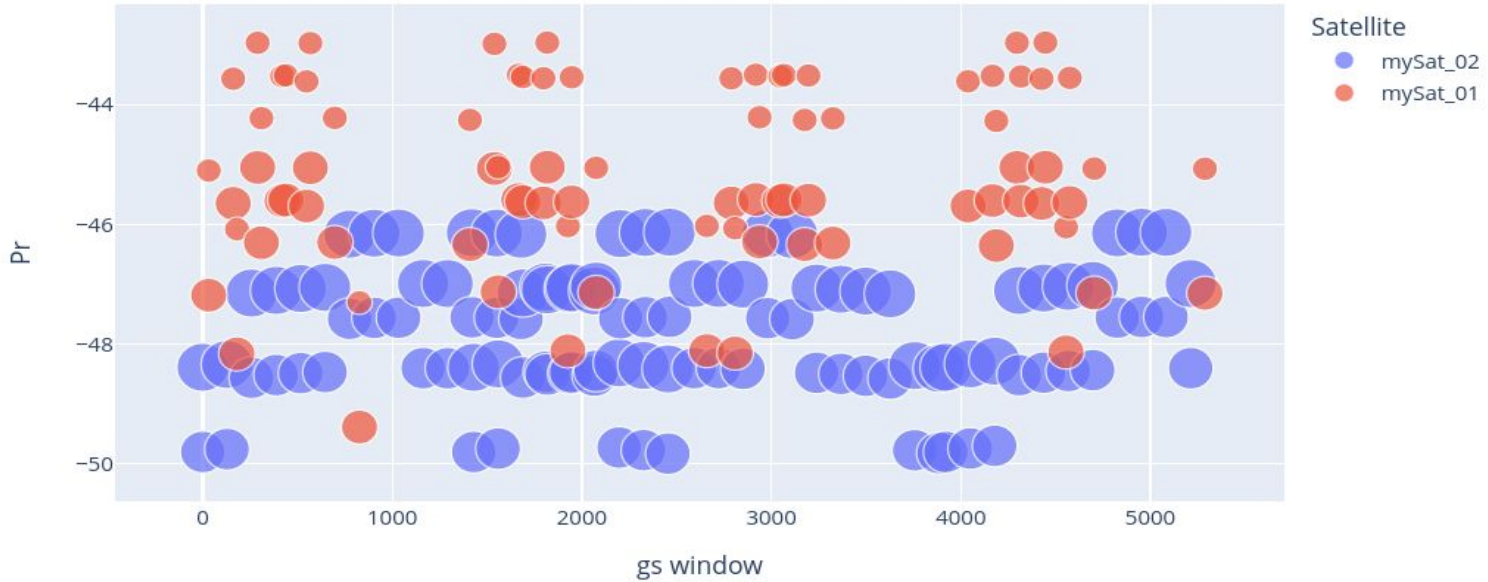
Quiet Skies

Two scoring metrics were pre-identified:

- Proportion of time above a RFI threshold: Comparison of the satellite power flux density to the radio observatory SEFD
- Number of frequency channels (average) impacted by satellites when above the interference threshold

$$\text{Is\_RFI}_{\text{Window\#i}} = \begin{cases} True & \text{, if EPFD}_{Sat} >= \text{EPFD}_{GS} \\ False & \text{, otherwise} \end{cases}$$

Quiet Skies



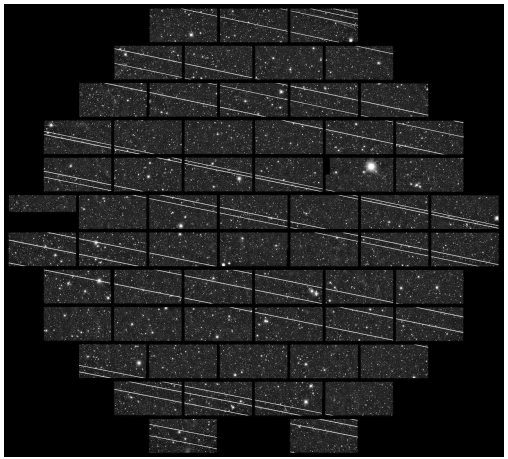
- Each dot represents a RFI for a whole integration time window
- Dot size represents number of frequency channels affected by RFI for a given satellite (designated by the dot color).
- Data obtained with mock satellite and radio telescope input parameters

A Dark and Quiet Skies Module for the Space Sustainability Rating

- Preliminary definition of a framework to quantify satellite impacts, account for efforts by operators, and assign a score allowing to incentivize satellite operators to account for their impact on astronomy
- Next steps includes further definition of modules sub-components and validation of the developed framework
- SSR is at intersection between research, industry, policy-makers, and has the potential to raise awareness and incentivize actions from operators

SSR is not the solution but contributes to the global efforts!

If you can't defeat your enemy, make him an ally

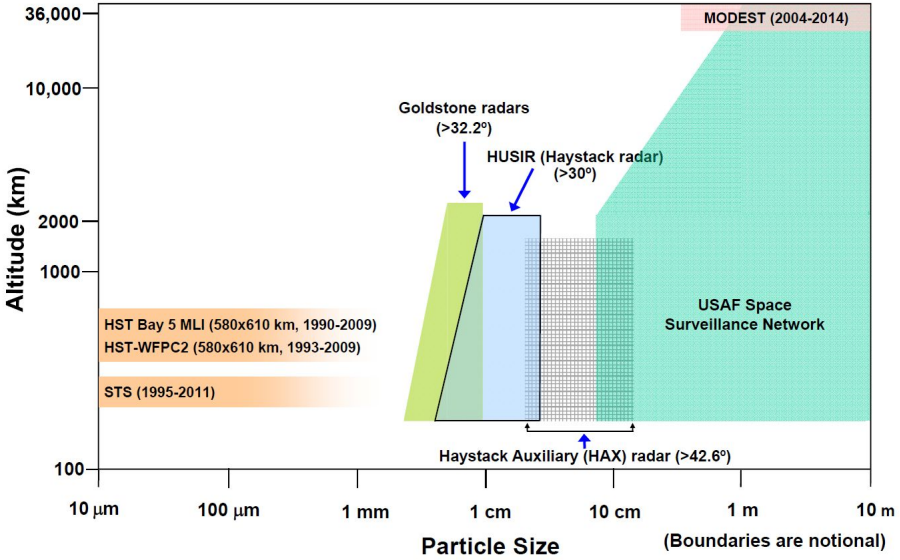


CTIO/NOIRLab/NSF/AURA/DECam DELVE Survey

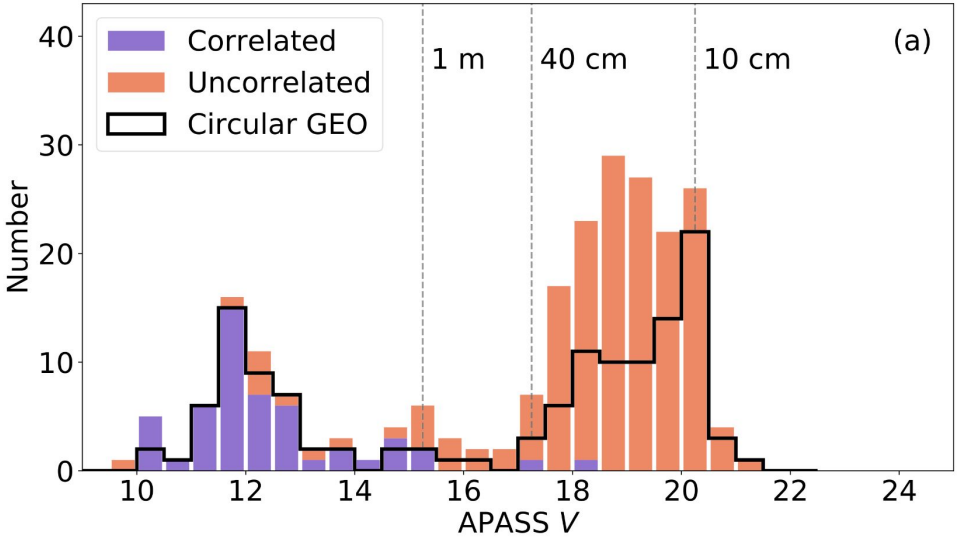
Leveraging existing data to better understand the evolution and current situation in orbit

What is the current situation?

- About 30,000 objects regularly tracked by Space Surveillance Networks
- Modells suggest 130 million particles from 1 mm to 1 cm

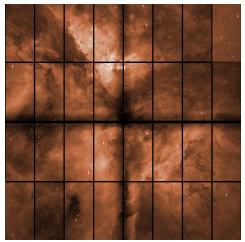


Measurement data used by the NASA Orbital Debris Program Office (ODPO) to describe the orbital debris populations in the near-Earth space environment. Credit: NASA ODPO.

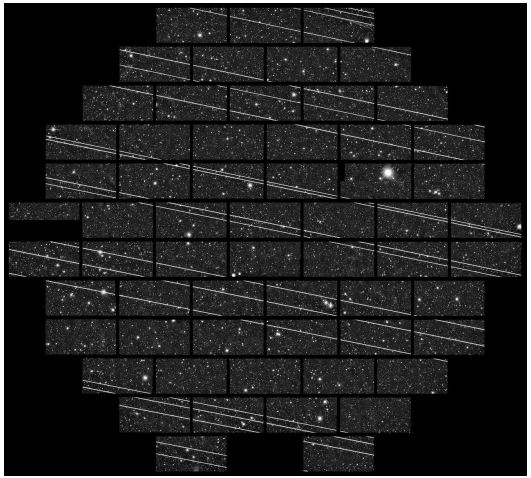


Brightness histogram for the detected objects during DebrisWatch 1 (James A. Blake et al., 2020)

Leveraging existing data



1°



2.2°

OmegaCAM @ ESO VLT Survey Telescope

- 2.6 m Telescope on Cerro Paranal
- 32 4k x 2k CCDs
- 436k images

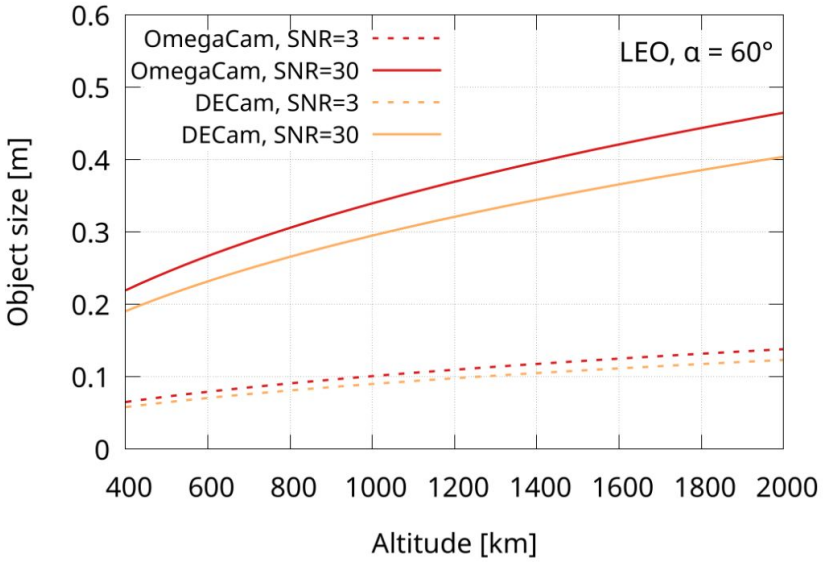
DECam @ Blanco Telescope

- 4 m Telescope on Cerro Tololo
- 62 4k x 2k CCDs
- 596k images

Leveraging existing data

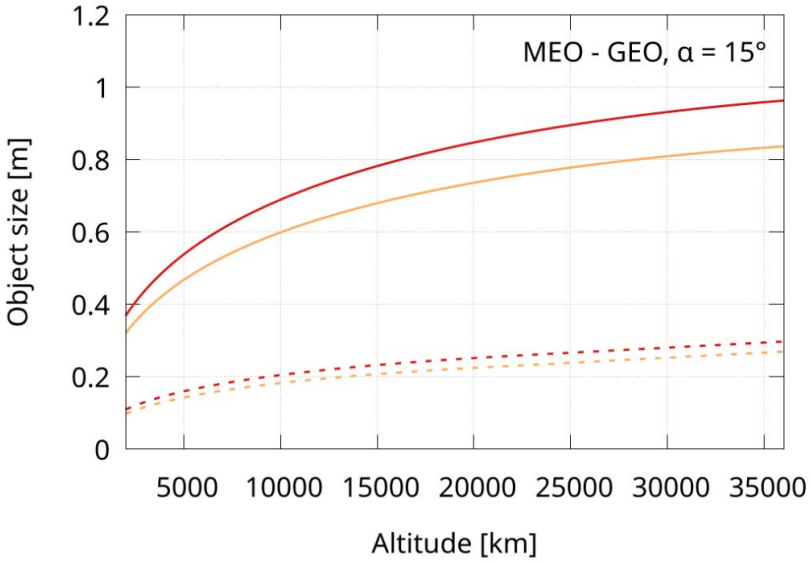
LEO

- Particles >0.07 m can be detected
- Particles >0.2 m bright enough for photometry



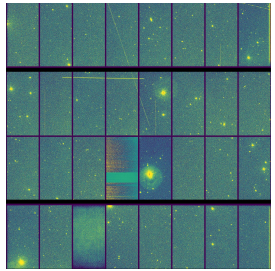
MEO to GEO

- Particles from 0.1 to 0.3 m can be detected
- Particles from 0.4 to 0.9 m bright enough for photometry

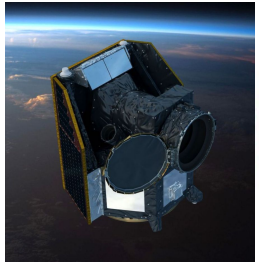


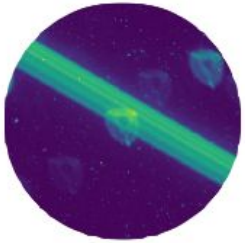
Leveraging existing data

- Harvesting large astronomical data archives for space debris observations
  - Machine learning based streak detection
  - Object correlation
  - Lightcurve extraction
- Photometric analysis
  - Further processing of the lightcurves to estimate rotation rates, object sizes and composition
  - Study the increasing impact of space debris on ground and space based observations
  - Investigate the untracked (small-sized) population of space objects

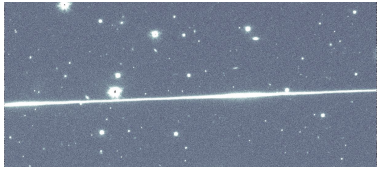


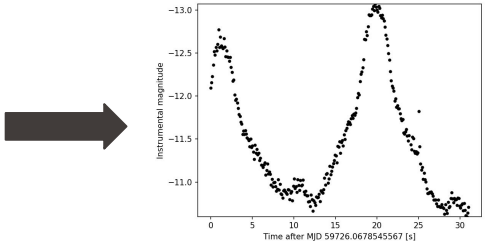
ESO VLT Survey Telescope (~500k images)

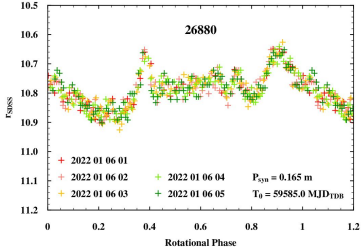




CHEOPS (>1M images)



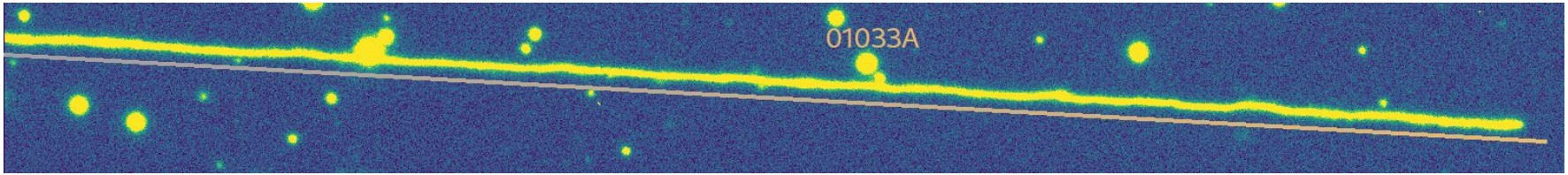




Hellmich, S. et. al. "Harvesting large astronomical data archives for space debris observations"

Streaks in VST/OmegaCAM data

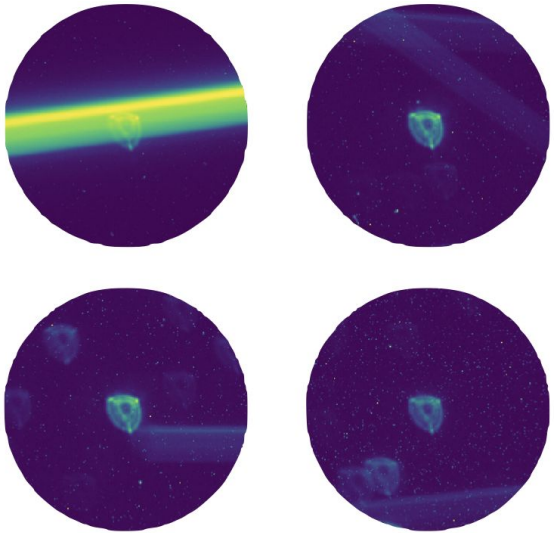
- Processed 1067 VST r band images acquired in January 2022
- 2871 streaks detected
- 1182 streaks identified with catalogued objects
- 214 individual objects observed

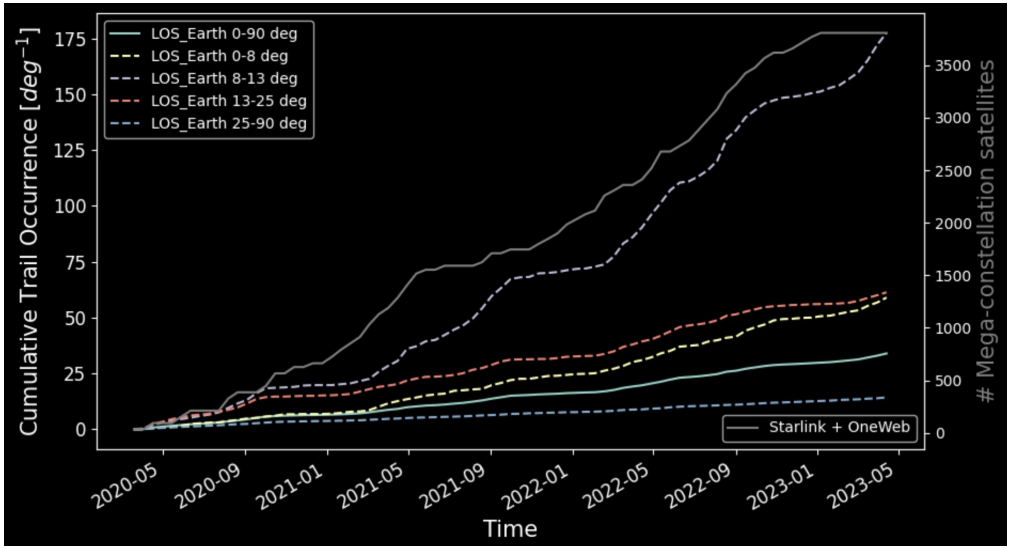


- Almost ⅔ of the detections can not be correlated -> untracked small debris?
- Valuable information can be obtained from such detections
  - Aftermath of collisions and fragmentation events
  - Size-frequency distribution of small orbital debris
- How to process?

Rachith, E. et. al. "A Novel Machine Learning Based Algorithm for Efficient Streak Detection"

Satellites observed by CHEOPS

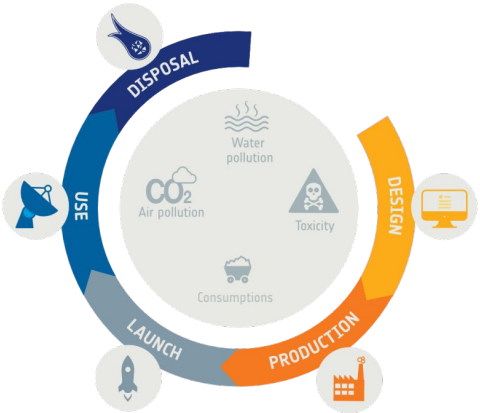




- 3200 streaks detected in over 1.25 million images
- No significant impact on CHEOPS science, but clear rising trend noticeable
- Improving detection algorithm and performing detailed photometric analysis

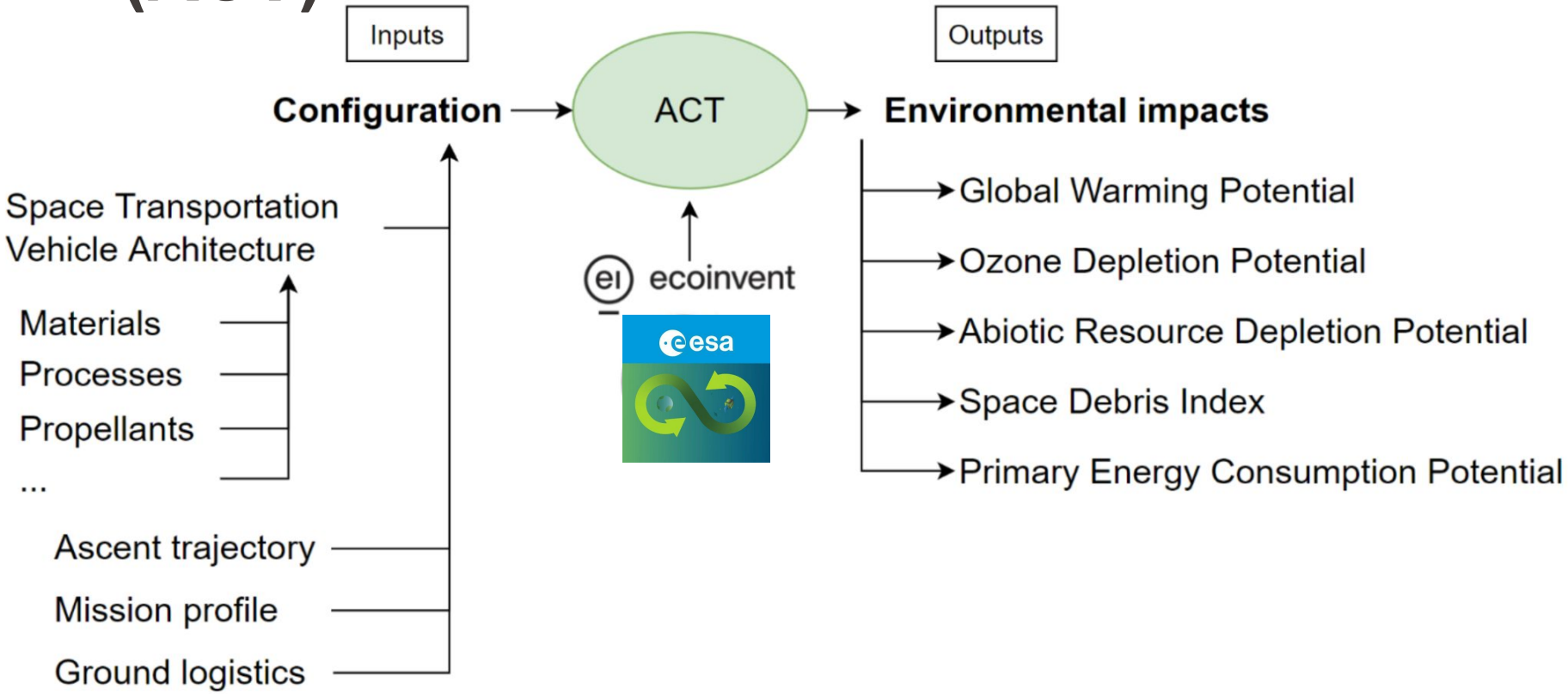
Billot, N. et. al. "In-situ observations of resident space objects with the CHEOPS space telescope"

Avoid burden shifting to other areas



ESA: life cycle stages

Assessment and Comparison Tool (ACT)



Udriot, M. et. al. "Rapid Life Cycle Assessment Software for Future Space Transportation Vehicles' Design - The Assessment and Comparison Tool"

Thank You!

- What's next?
  - Finalize DQS module for SSR
  - Continue processing archive data
  - Intensive involvement in IAU CPS
  - Swiss Space Sustainability Research Days in Les Diablerets, Jan 2025!

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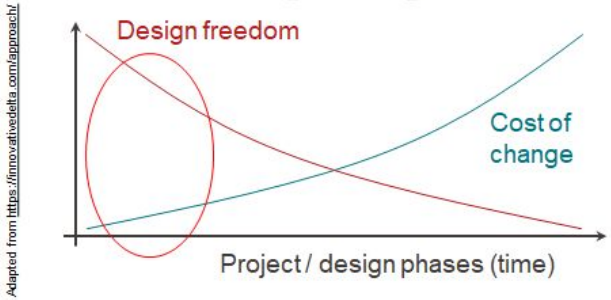
Our projects in sustainability *for* space



- To support engineers with little LCA knowledge
- To highlight environmental hotspots
- Using high-level system data

Handbook on sustainable practices for spacecraft mission design
Concurrent Engineering
Assessment and Comparison Tool (ACT)

Precalculated impact **scores** ·	material/energy/etc. **amount** =	**final impact score**
(background databases)	*(specified in ACT)*	*(environmental impacts of configuration)*

ecoinvent + esa

+ prospective

https://www.esa.int

Models:
Parameters
LCA datasets