# Green Space Logistics: Rapid Assessment and Comparison of Space Transportation Vehicles' Environmental Impacts for Design Trade-Offs

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# Introduction - eSpace

eSpace:

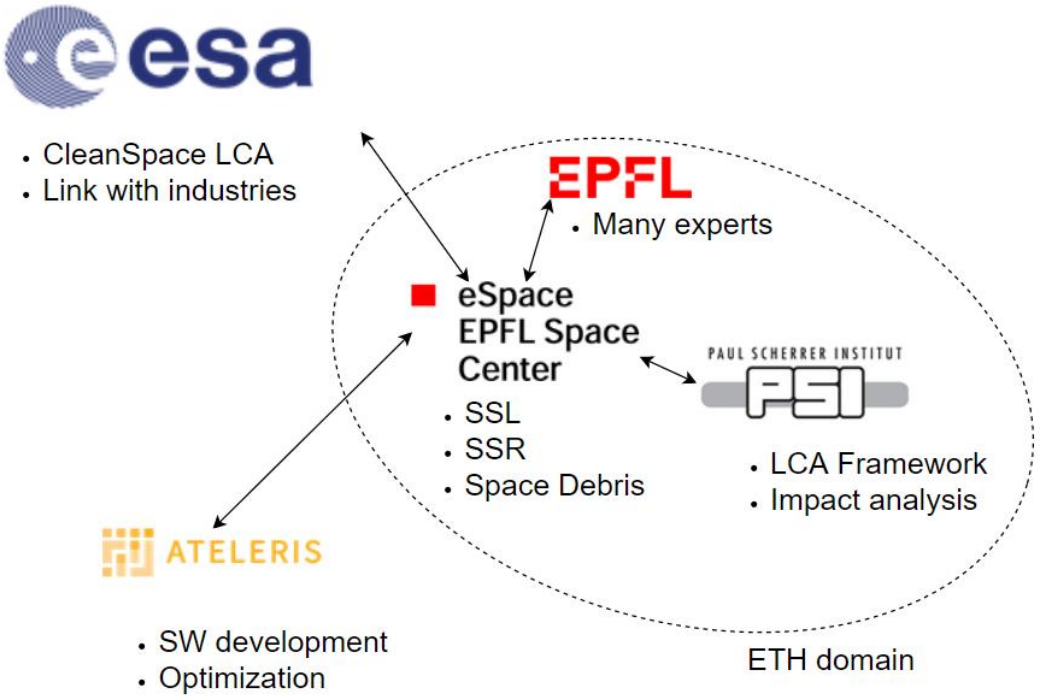
- ~12 staff + students
- 2 research **hubs** (Sustainable Space Logistics and Lunar Research)
- Operator of the Space Sustainability Rating (**SSR**)
- Several **partnerships** with labs and industry (eg. Clearspace)

Myself:

- EPFL graduate, master thesis on the SSR implementation, EPFL Rocket Team
- Full time employee on projects about **LCA** and space logistics
- Extension of SSR for launch vehicle (**LVSR**)
- Concurrent engineering (CDF)

# Introduction – Green Space Logistics (1)

- Contract with ESA FLPP
- Swiss consortium
- 1 year project
- Iterative development



# Introduction – Green Space Logistics (2)

Automatize LCA for design trade-off of future launch vehicles and space transportation vehicles

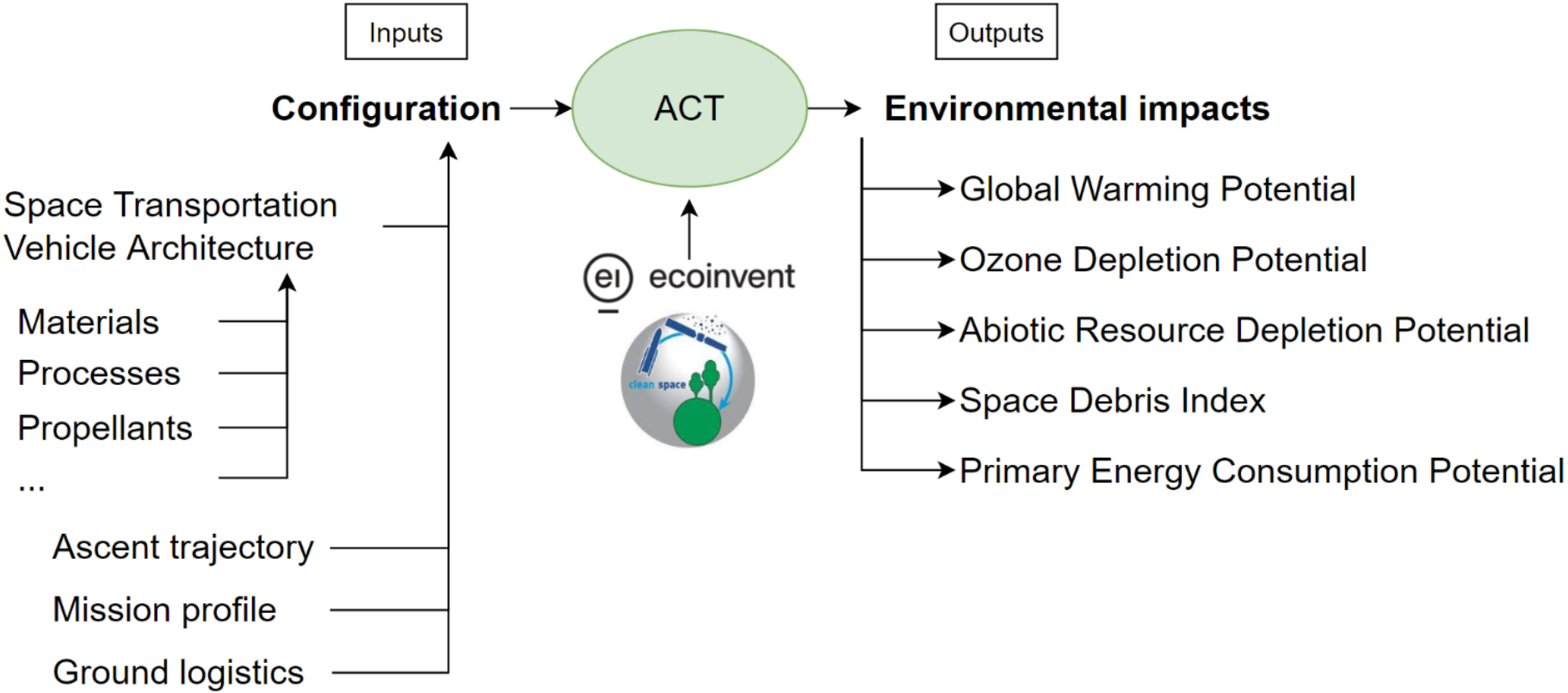
Assessment and Comparison Tool (**ACT**):

- A tool to highlight environmental hotspots
- A useful, quick LCA tool for ESA engineers
- A modular tool that can get more complex

What it will <u>not</u> be

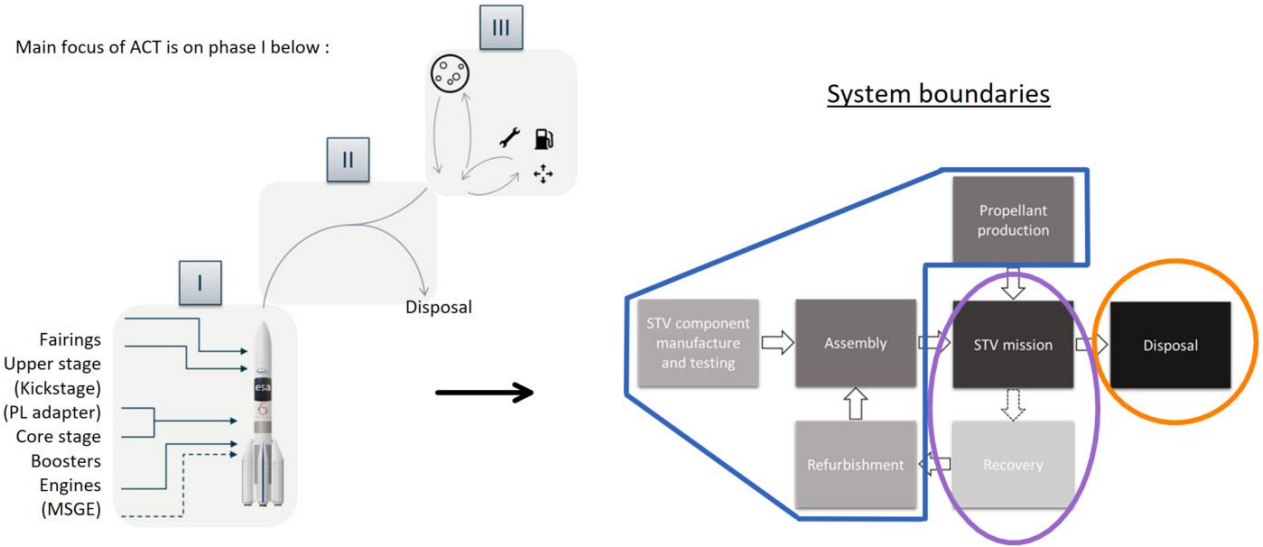
- A complete, detailed LCA tool
- A generator of eco design options

# Introduction – Green Space Logistics (3)



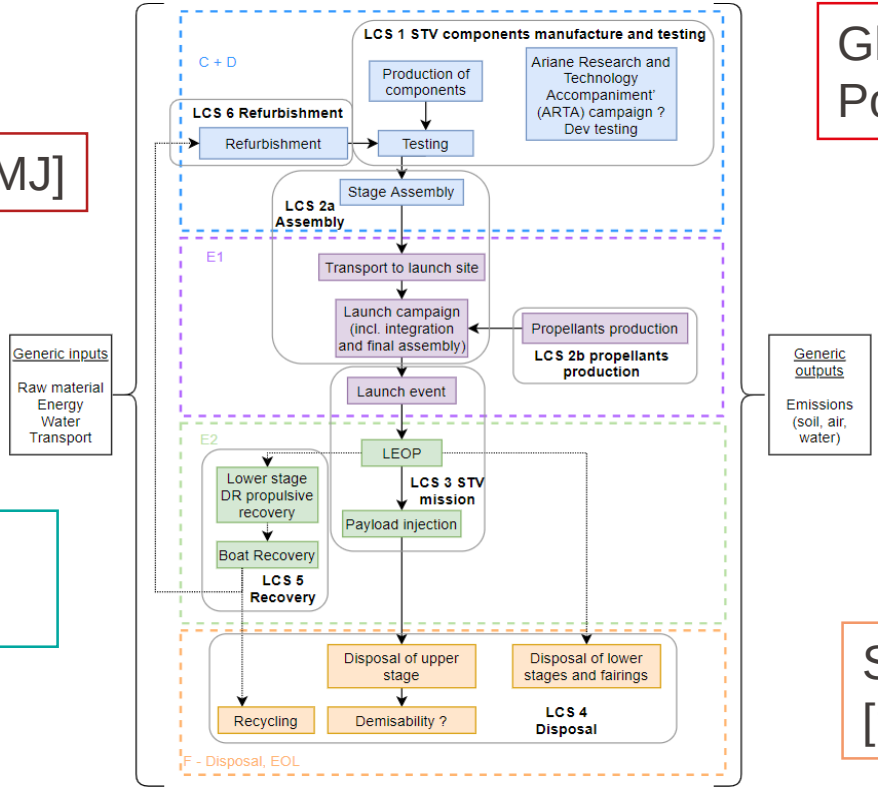
# Functional units

- FU 1: One Space Transportation Vehicle mission in fulfilment of its requirements
- FU 2: To place X tons of payload into orbit Y
- FU 3: To remove X tons of debris from orbit Y
- FU 4: 1 launch of [name of launcher]
- Other FU at equipment level ?



# Assessment and Comparison Tool

## LCA boundaries + indicators




Energy consumption [MJ]

Global Warming Potential [kg $CO_2$-eq]

Ozone Depletion Potential [kg CFC-11-eq]

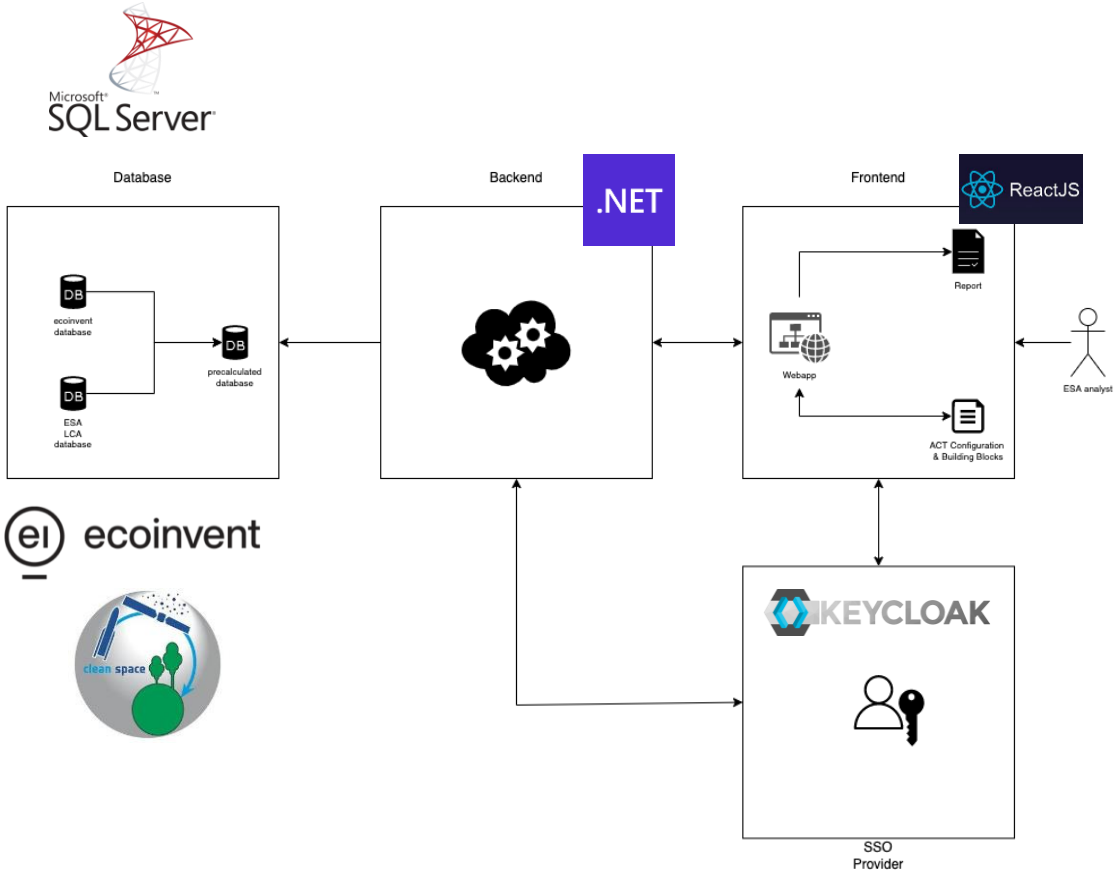
Abiotic Resources Depletion [kg Sb-eq]

Space debris index [pot. fragments*yrs]

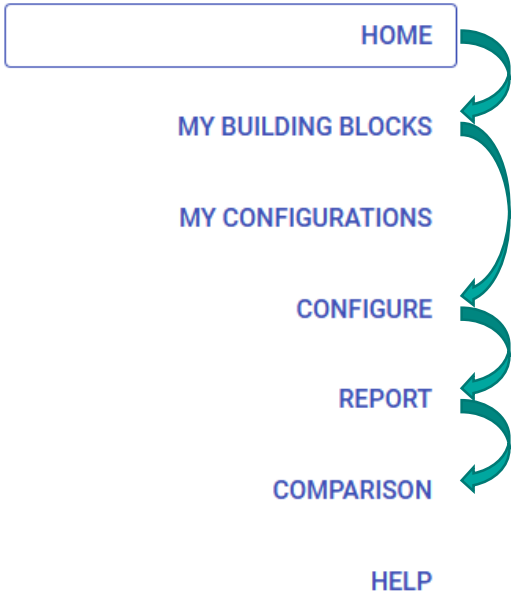
# Assessment and Comparison Tool

## SW structure

- Input parameters
- Building blocks
- Configurations
- LCA databases
  → precalculated
- Website UI

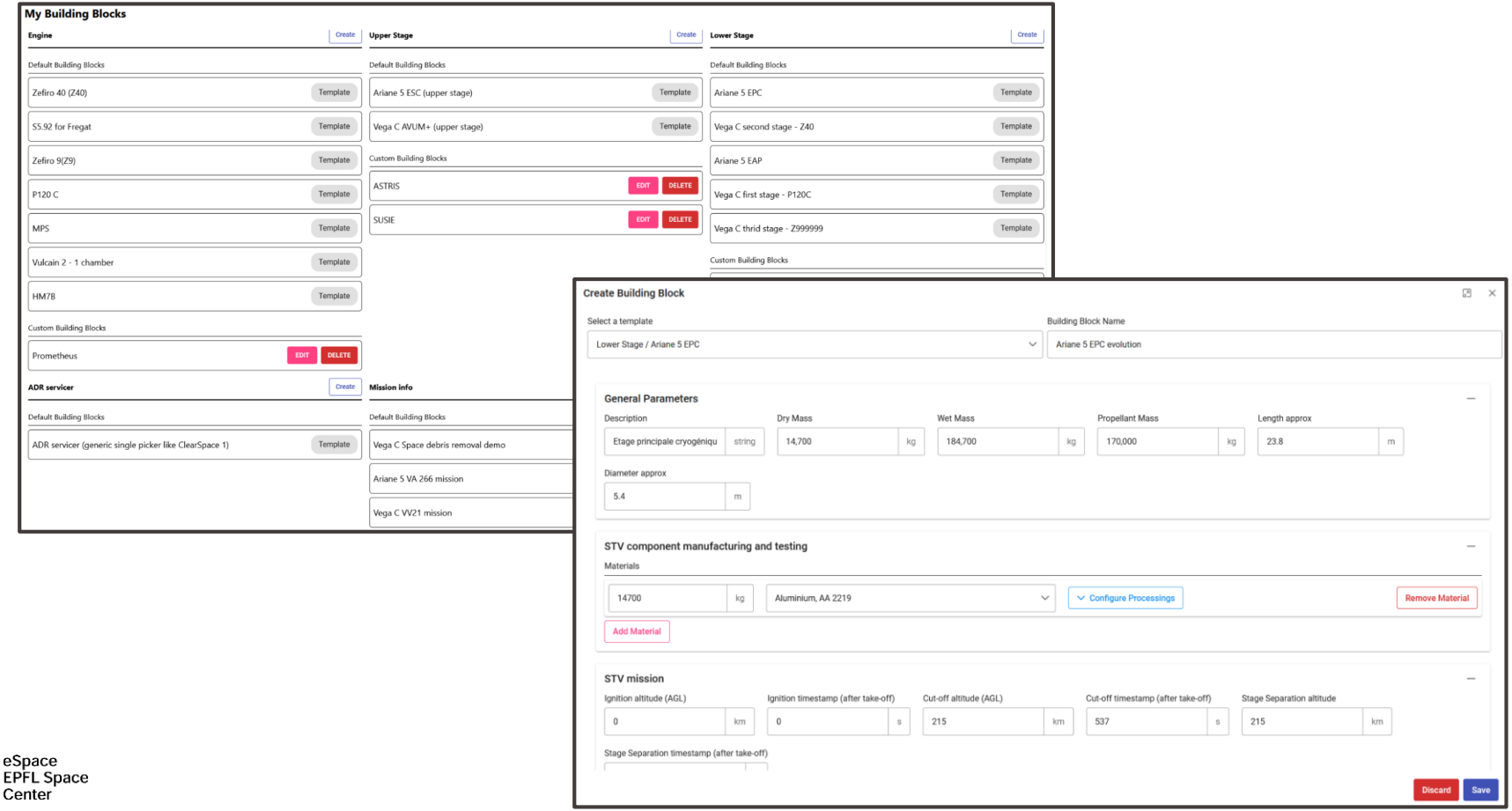


# User process

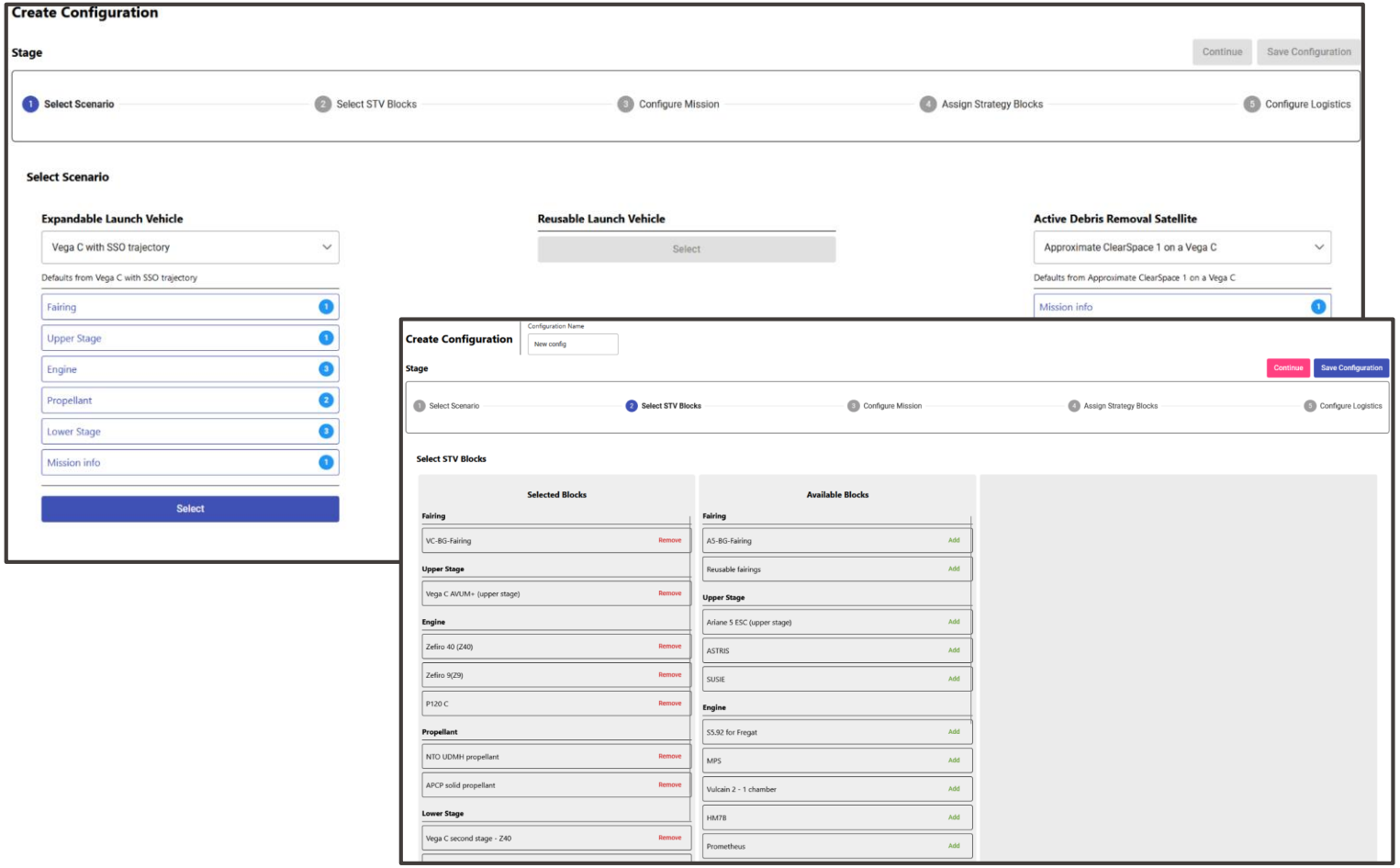



1. Create new STV building blocks
   Select LCA datasets (LCI)
2. Define a new configuration
3. Save and compute impacts of the configuration
4. Select several configurations for comparison

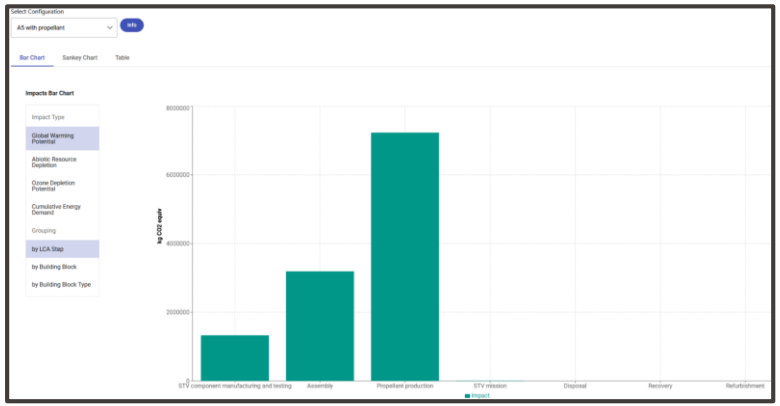
# The user interface - Parametrization (inputs)



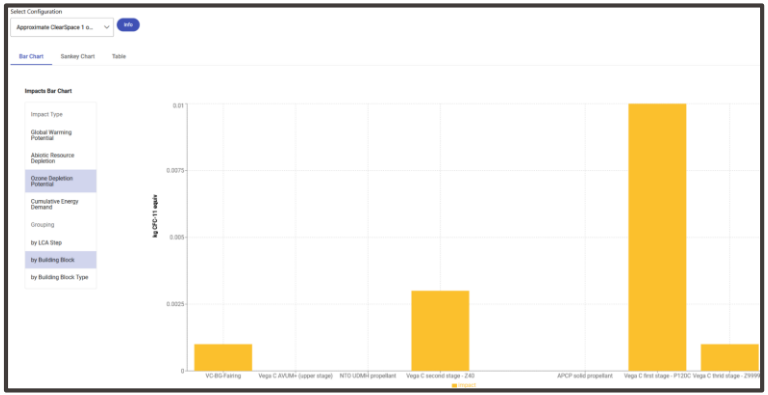
# The user interface - Configuration (inputs)

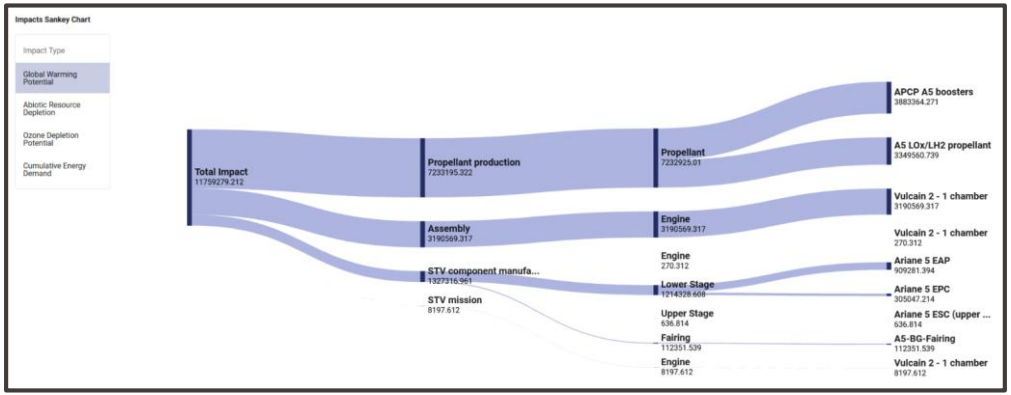


# The user interface - Report (outputs)




- Results representations
- Several impacts
- Several grouping
- Contribution analysis



# Challenges of the project

- A lot of assumptions needed without real data
- LCA database format compatibility
- Inconsistencies between foreground/background data (eg. energy mix)
- (New) LCA methodology aspects (eg. reusability, EOL, space debris)
- Implementation of a space debris index
- Integration of the user / customer feedbacks

# Assumptions of how a “greener” STV would look like

**Needs confirmation with LCA results**

Definition of “green”?

→ Needs measurable Key Performance Indicators to be reached

→ Single score formula from Green4ESA workshop

A “greener” launch vehicle would probably use:

- Closed cycle engine running on *clean* methane or *clean* hydrogen
- No SRM boosters
- Space debris mitigations strategies for orbital/kick stage
- Materials sourced at suppliers with lower impacts

About the reusability, trade-offs are needed

# Ecodesign: Green4ESA (workshop)

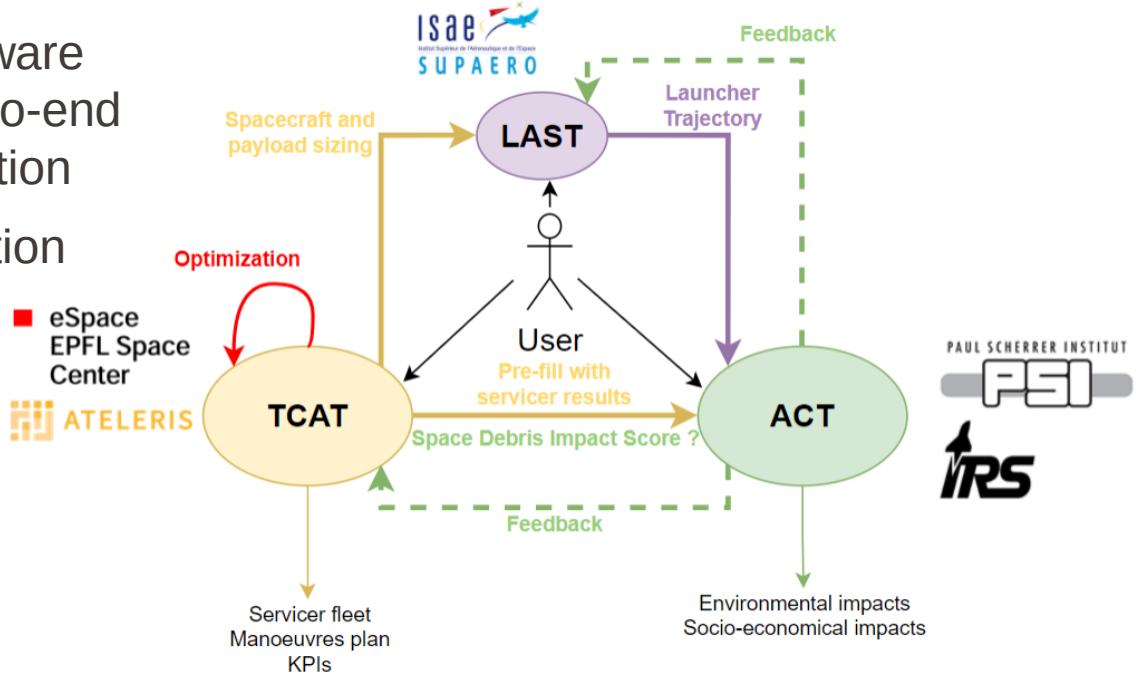
- Single score formula to help trade-off architectures
- Can the weights be fine-tuned ? Trade-offs allowed ? Depending on :
  - The segment
  - The year of use
  - New research data
  - New hotspots identified
  - …

→ How to adapt it, mechanism for evolution ?

→ Inclusion of new LCA indicators / elements (to fill gaps) in the formula
  - Eg. Space debris index
  - Atmospheric impacts ← high altitude emissions characterization factors

# GSL+ for 2023+

- Extend the scope of the assessment
- Improve our models and fill some of the knowledge gap
- Connect with other software → comprehensive end-to-end space logistics optimisation
- Move towards digitalisation



# Conclusion

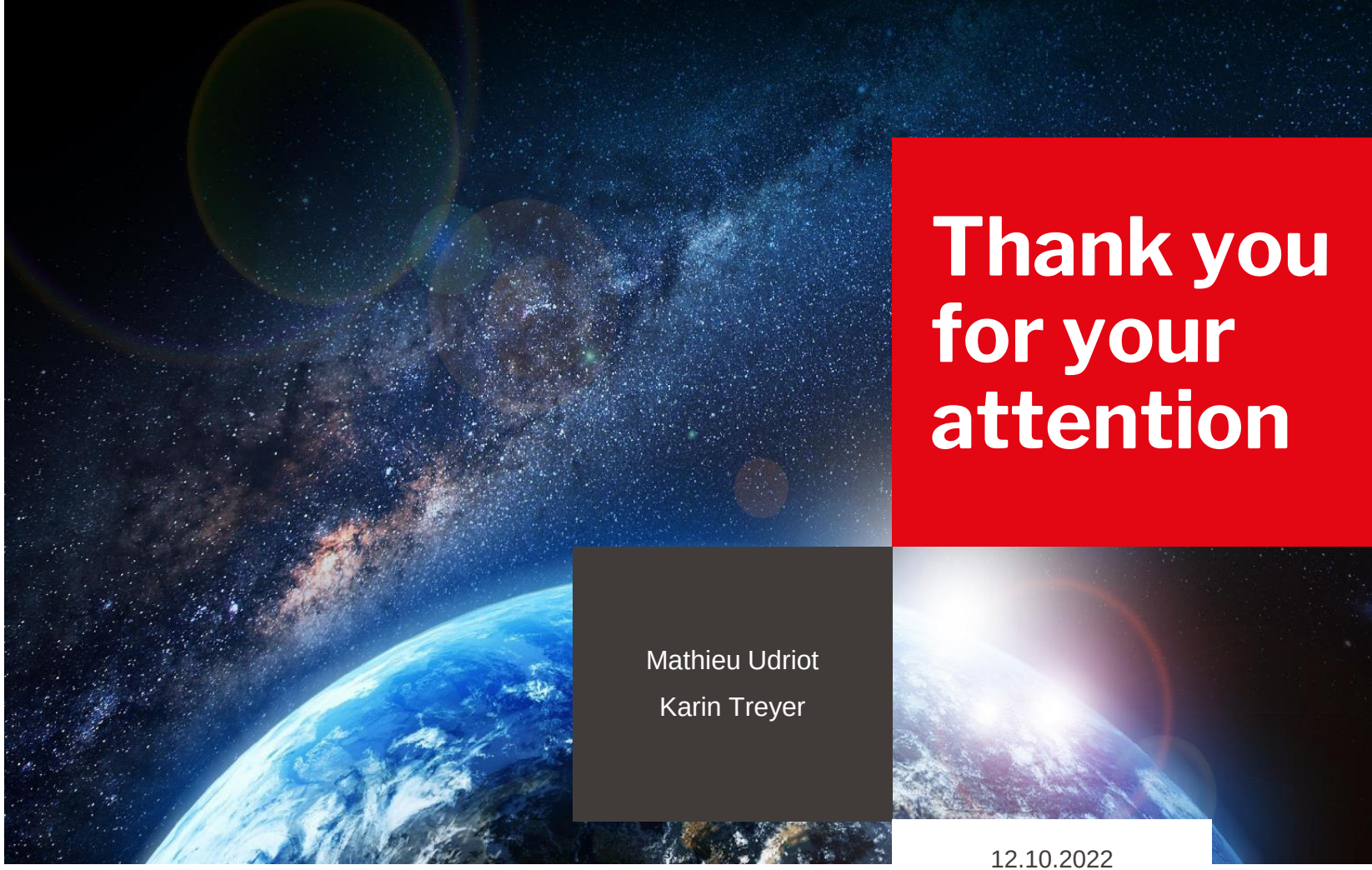
- Rapid LCA software in development
- Knowledge gaps identified

→ Need new LCA datasets and more confidence in data

→ Need an aggregating formula for launchers

- FLPP to test different architectures of STVs and trade-off design options
- ACT to be used in our CDF ?
  → test ecodesign solutions

Concurrent Design Facility



# Thank you for your attention

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