

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)

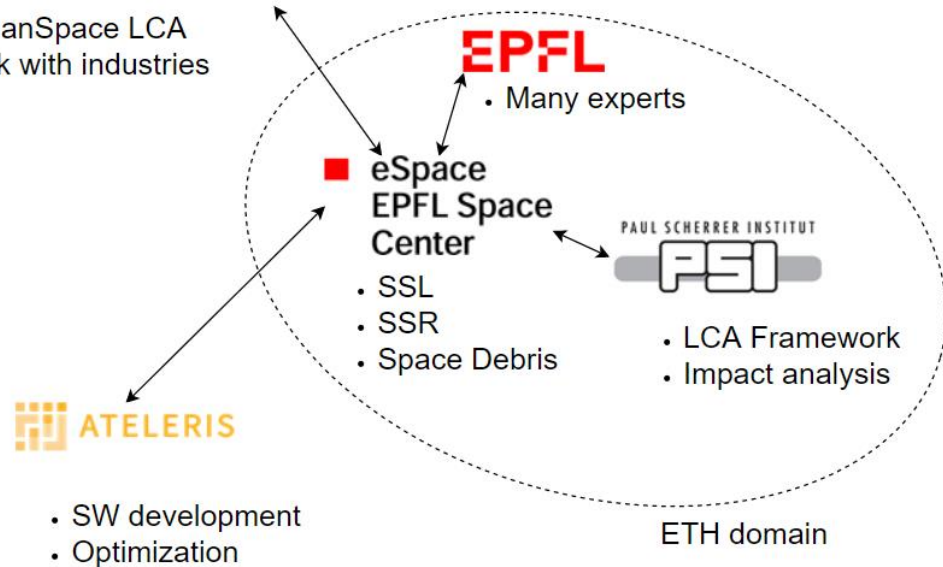


Introduction – Green Space Logistics (1)

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



- CleanSpace LCA
- Link with industries



Introduction – Green Space Logistics (2)

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

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

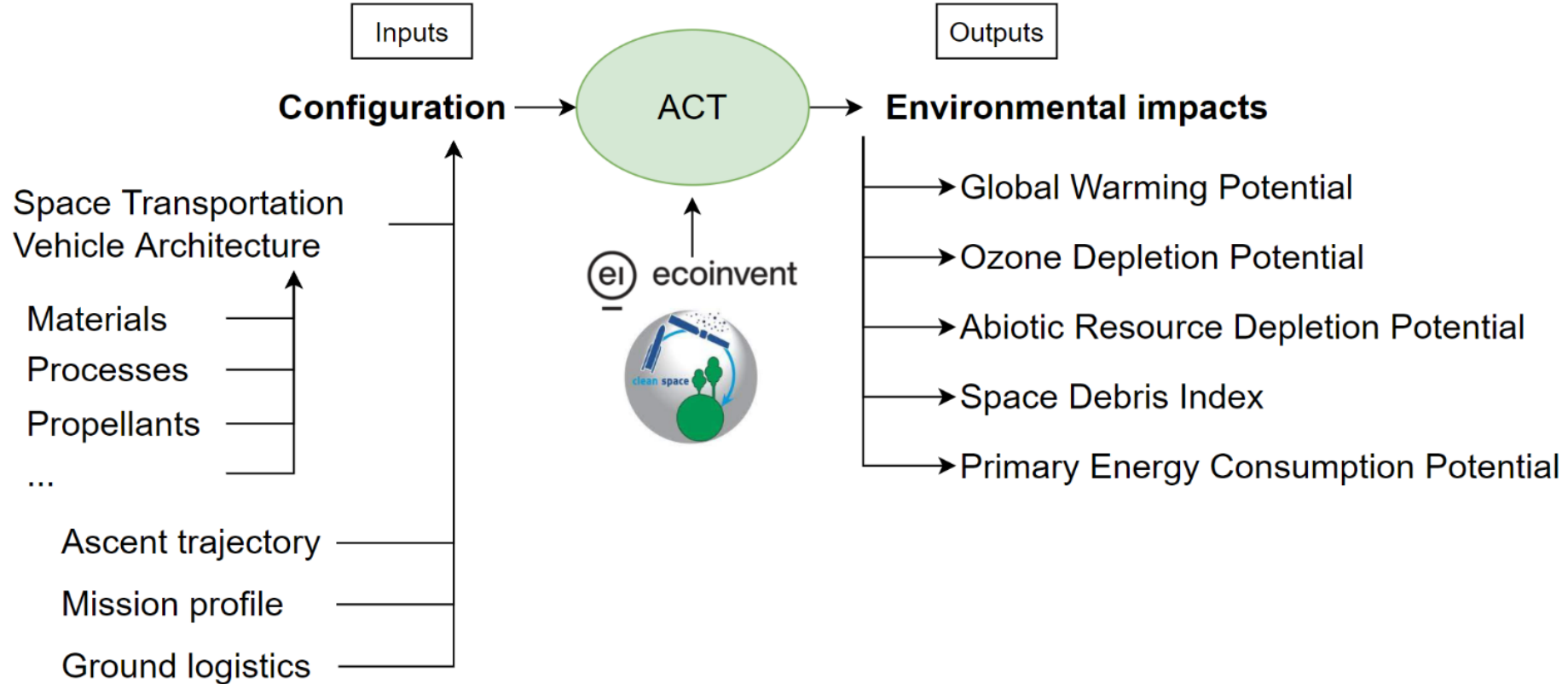
- A tool to highlight environmental hotspots
- A useful, quick LCA tool for ESA engineers
- A modular tool that can get more complex



What it will not be

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

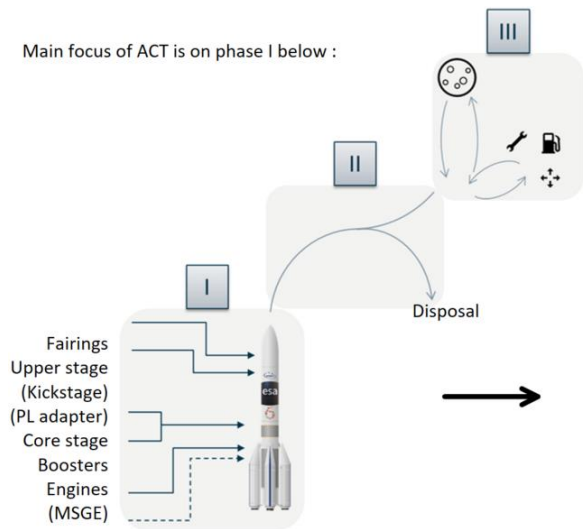
Introduction – Green Space Logistics (3)



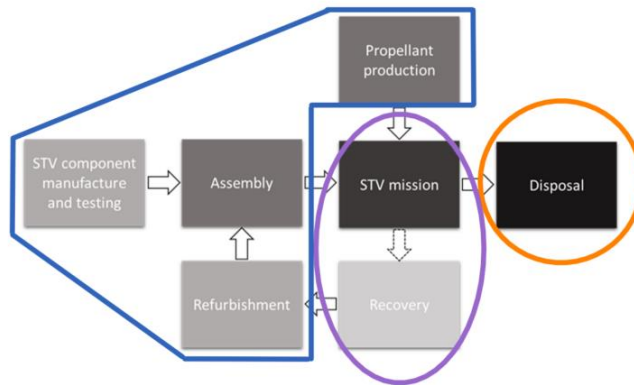
Functional units

- 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 ?

Main focus of ACT is on phase I below :



System boundaries



Assessment and Comparison Tool

LCA boundaries + indicators

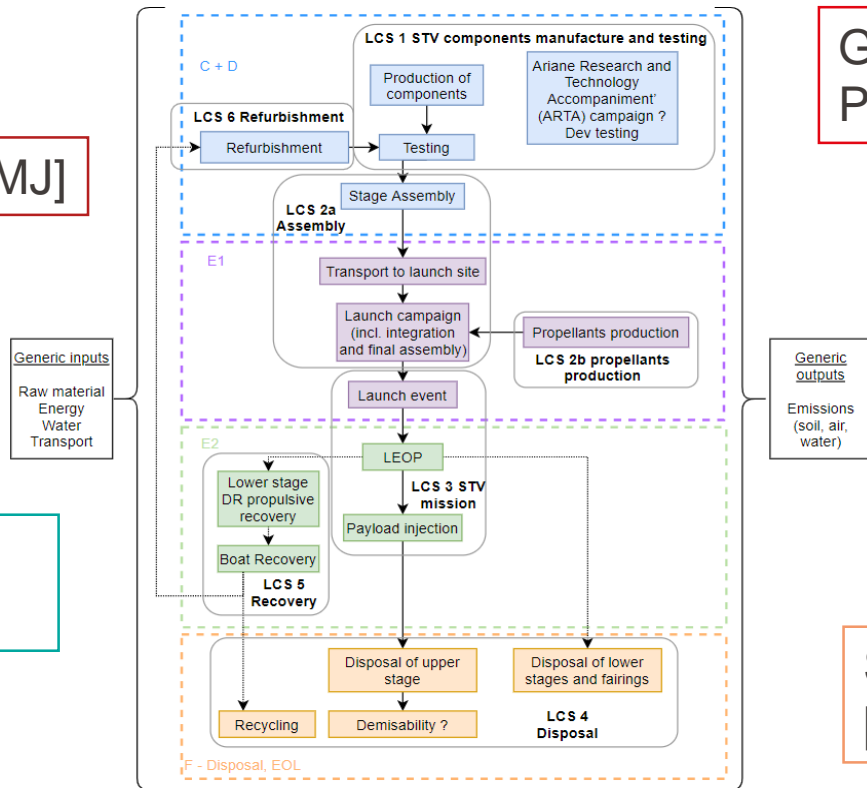
Energy consumption [MJ]

Abiotic Resources
Depletion [kg Sb-eq]

Global Warming
Potential [kg CO₂-eq]

Ozone Depletion
Potential [kg
CFC-11-eq]

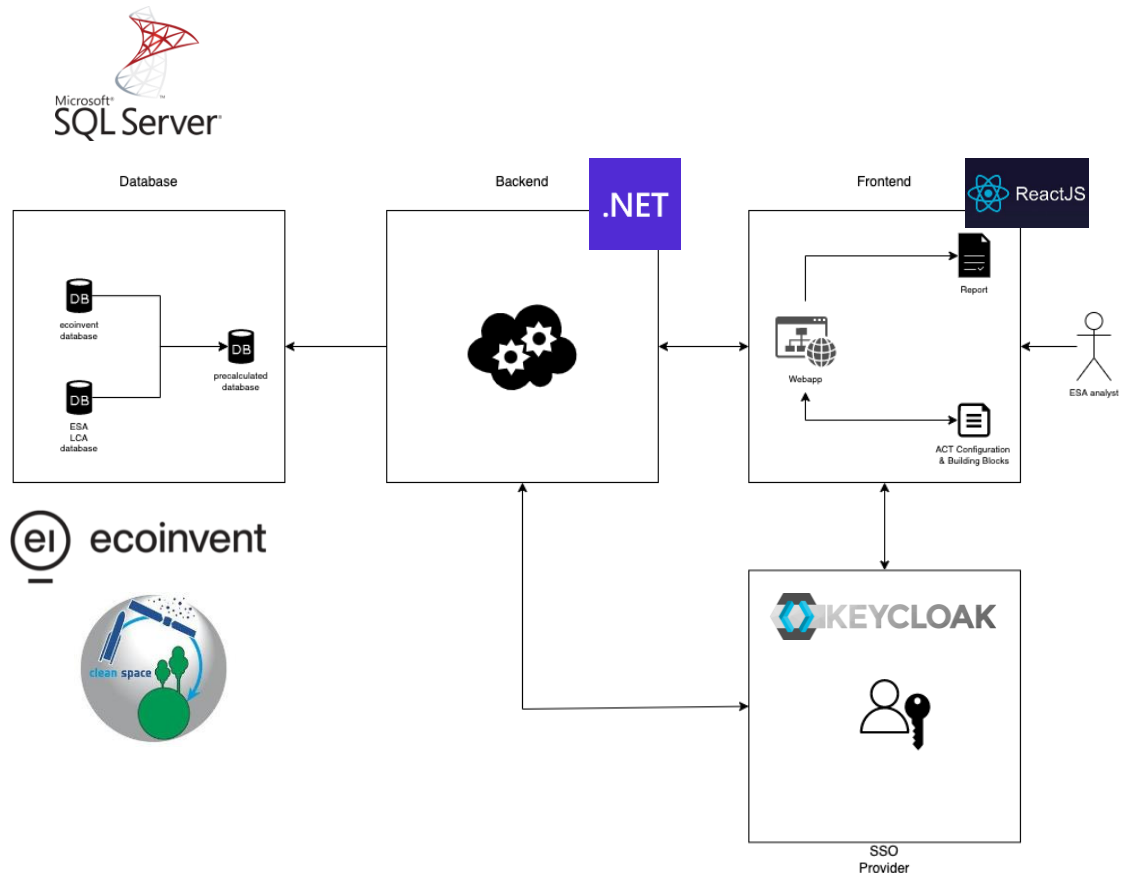
Space debris index
[pot. fragments* yrs]



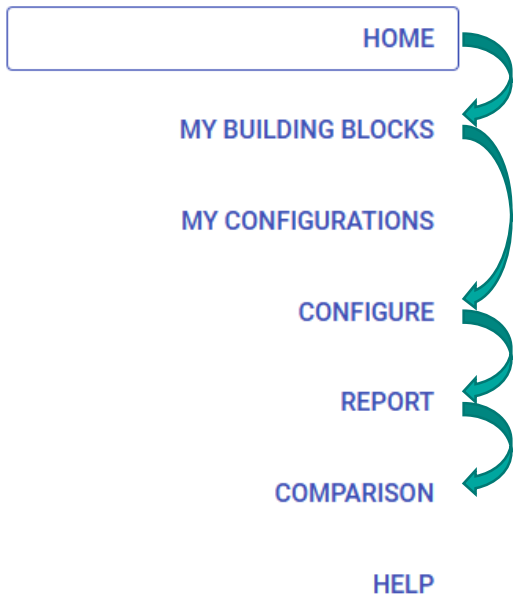
Assessment and Comparison Tool

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)

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My Building Blocks

Engine [Create](#)

Default Building Blocks

- Zefiro 40 (Z40) [Template](#)
- S5.92 for Fregat [Template](#)
- Zefiro 9(Z9) [Template](#)
- P120 C [Template](#)
- MPS [Template](#)
- Vulcain 2 - 1 chamber [Template](#)
- HM78 [Template](#)

Custom Building Blocks

- Prometheus [EDIT](#) [DELETE](#)

ADR servicer [Create](#)

Default Building Blocks

- ADR servicer (generic single picker like ClearSpace 1) [Template](#)

Upper Stage [Create](#)

Default Building Blocks

- Ariane 5 ESC (upper stage) [Template](#)
- Vega C AVUM+ (upper stage) [Template](#)

Custom Building Blocks

- ASTRIS [EDIT](#) [DELETE](#)
- SUSIE [EDIT](#) [DELETE](#)

Lower Stage [Create](#)

Default Building Blocks

- Ariane 5 EPC [Template](#)
- Vega C second stage - Z40 [Template](#)
- Ariane 5 EAP [Template](#)
- Vega C first stage - P120C [Template](#)
- Vega C third stage - Z999999 [Template](#)

Custom Building Blocks

Create Building Block

Select a template: Lower Stage / Ariane 5 EPC

Building Block Name: Ariane 5 EPC evolution

General Parameters

Description	Dry Mass	Wet Mass	Propellant Mass	Length approx
Etage principale cryogénique <small>string</small>	14,700 <small>kg</small>	184,700 <small>kg</small>	170,000 <small>kg</small>	23.8 <small>m</small>

Diameter approx: 5.4 m

STV component manufacturing and testing

Materials

14700 <small>kg</small>	Aluminium, AA 2219	Configure Processings	Remove Material
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[Add Material](#)

STV mission

Ignition altitude (AGL): 0 <small>km</small>	Ignition timestamp (after take-off): 0 <small>s</small>	Cut-off altitude (AGL): 215 <small>km</small>	Cut-off timestamp (after take-off): 537 <small>s</small>	Stage Separation altitude: 215 <small>km</small>
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Stage Separation timestamp (after take-off):

[Discard](#) [Save](#)

The user interface - Configuration (inputs)

Create Configuration

Stage

1 Select Scenario
2 Select STV Blocks
3 Configure Mission
4 Assign Strategy Blocks
5 Configure Logistics

Select Scenario

Expandable Launch Vehicle

Vega C with SSO trajectory

Defaults from Vega C with SSO trajectory

Fairing

Upper Stage

Engine

Propellant

Lower Stage

Mission info

Select

Reusable Launch Vehicle

Select

Active Debris Removal Satellite

Approximate ClearSpace 1 on a Vega C

Defaults from Approximate ClearSpace 1 on a Vega C

Mission info

Create Configuration

Configuration Name
New config

Continue Save Configuration

Stage

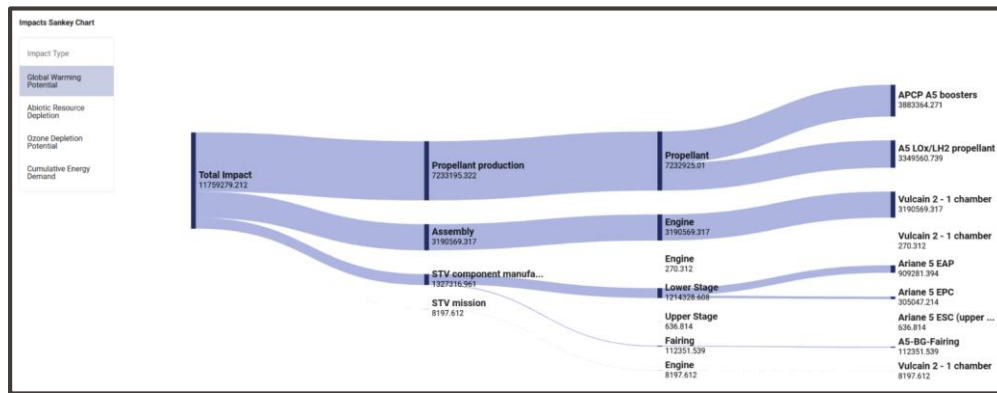
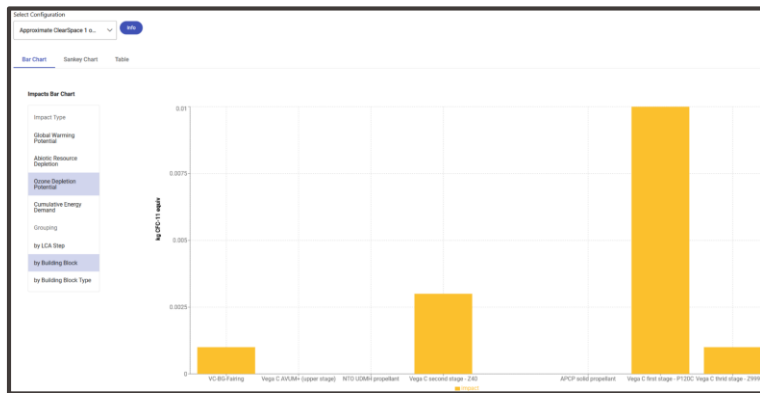
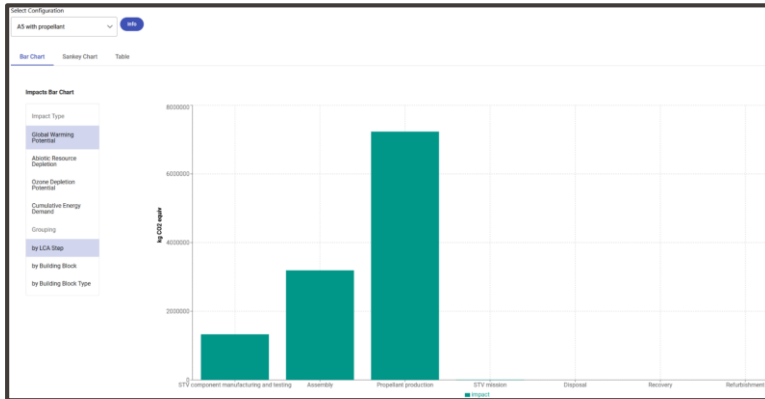
1 Select Scenario
2 Select STV Blocks
3 Configure Mission
4 Assign Strategy Blocks
5 Configure Logistics

Select STV Blocks

Selected Blocks	Available Blocks
Fairing VC-BG-Fairing Remove	Fairing AS-BG-Fairing Add Reusable fairings Add
Upper Stage Vega C AVUM+ (upper stage) Remove	Upper Stage Ariane 5 ESC (upper stage) Add ASTRIS Add SUSIE Add
Engine Zefiro 40 (Z40) Remove Zefiro 9(Z39) Remove P120 C Remove	Engine S5.92 for Fregat Add MPS Add Vulcain 2 - 1 chamber Add HMTB Add Prometheus Add
Propellant NTO UDMH propellant Remove APCP solid propellant Remove	
Lower Stage Vega C second stage - Z40 Remove	

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

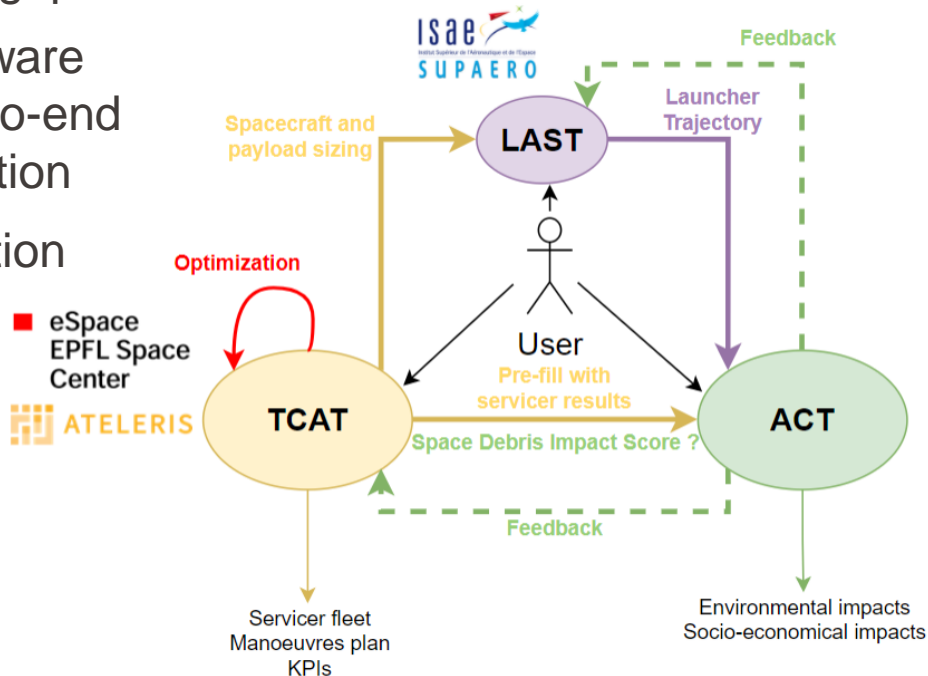


Ecodesign: Green4ESA (workshop)

- 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



The background of the slide is a deep space image featuring the Milky Way galaxy, a bright sun or star on the right, and the blue curve of the Earth at the bottom.

**Thank you
for your
attention**

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Karin Treyer