Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: SUSTSP
Corresponding author: UDRIOT Mathieu
e-mail of corresponding author: mathieu.udriot@epfl.ch
Type: Oral
Status of corresponding author: Regular

Title
Rapid Life Cycle Assessment Software for Future Space Transportation Vehicles' Design
Test cases with present and prospective data to identify science and technology gaps

Authors
Mathieu UDRIOT [1], Karin Treyer [2], Orell Bühler[3], Laszlo Etesi[3], Emmanuelle David [1], Valère Girardin[4]*

** Corresponding author*
[1] EPFL Space Center (eSpace), Ecole Polytechnique Fédérale de Lausanne, 1015 Lausamme, Switzerland, mathieu.udriot@epfl.ch
[2] Technology Assessment Group, Laboratory for Energy Systems Analysis, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland
[3] Ateleris GmbH, 5200 Brugg, Switzerland
[4] Future Launchers Preparatory Programme, Space Transportation, European Space Agency, 75012 Paris, France

Abstract
As opposed to performance, cost, and programmatic metrics, impacts on Earth or on the space environment have not been drivers of space systems and missions design until recently. This is changing thanks to a shift of mindset, growing risk related to space debris, and a need to anticipate regulations that are likely to be applied to the space industry.

The Assessment and Comparison Tool (ACT) software is made to create configurations of space transportation vehicles (STV) and rapidly perform their life cycle assessments (LCA) based on user-known data and assumptions. The background inventory is pre-calculated by aggregating datasets from LCA databases, so user can input high level systems values, and select the relevant LCA datasets used to compute the environmental impacts of a system. This tool will be used in early design trade-offs, to better select the key technology bricks of future STVs, to adapt the design to minimise environmental impacts.
ACT is being developed in the frame of a project with the ESA Future Launchers Preparatory Programme since 2022 by a consortium of Swiss entities: EPFL Space Center (eSpace), Paul Scherrer Institute, and Ateleris GmbH. The project follows previous research conducted at eSpace that focused on space logistics modelling and space sustainability.

Early analyses are crucial to help engineers make design choices that can reduce environmental impacts, a process called ecodesign [1]. The vehicles' production, material sourcing, emissions, operational phase, transport, and other contributions from the product's entire life cycle are compiled to assess impacts with LCA indicators. Environmental hotspots, phase(s) of a vehicle's mission or building block(s) that contribute to a large share of the total impacts, can be highlighted, which helps prioritise research and development to mitigate them.
The scope and boundaries of the LCA are adapted to space systems, based on the dedicated ESA handbook [2] and the consortium's expertise: On top of common indicators, a space debris index score is used to assess impacts on the space environment, and preliminary estimations of the atmospheric emissions during the launch are computed as mass flows. Further, ACT gives its users the possibility to adapt the background database to future scenarios. This is important due to the expected reaction of mankind to climate change threats in the

coming decades, which will drive changes in energy systems and industrial processes relevant for future launch vehicles and missions, to minimise their environmental impacts.

The tool is designed to be robust to evolution, embedding a modular data model allowing for scope extensions and implementation of newer calculation methodologies, once the scientific research is ready. Indeed, science gaps for the LCA of an STV have been identified, including the impacts of high-altitude emissions during the launch, and the particles and gases generated during the re-entry. Finally, technology gaps can be highlighted from the computed impacts and the will to mitigate part of them using ecodesign processes.

This paper presents the Assessment and Comparison Tool and details the ongoing and needed research to fill knowledge gaps in LCA for space systems. Test cases of imaginary future space transportation vehicles are assessed using ACT to introduce its functionalities and capabilities. Ideas for reusability, vehicles for new launch architectures, and new propellant or materials are discussed regarding environmental impacts, before looking at possible future development of the tool.

References

[1] ESA Space Safety, Clean Space, “ecodesign”, https://www.esa.int/Space_Safety/Clean_Space/ecodesign, consulted on 24.01.2023.
[2] ESA LCA Working Group, “Space system Life Cycle Assessment (LCA) guidelines”, 2016.