

LCA IN SPACE

CURRENT STATUS AND FUTURE DEVELOPMENT



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Background

- Assumption: The future and outlast of humanity lies within the exploration and colonisation of space.
- The Protection of earth *and* space environment is therefore essential for human survival.
- The LCA methodology in its current state might not be capable to address impacts to the space environment.



Photo: Greg Rakozay

Figure 1: Survival of the human race only through colonisation of other planets? Steven Hawking: "Although the chance of a disaster to planet Earth in a given year may be quite low, it adds up over time [...]. By that time, we should have spread out into space, and to other stars."

Questions

- What is the state of the art of environmental impact assessment in space? Which impacts on space already exist, which LCAs concerning space activities and which regulations in space? (Literature research)
- Which regionalization approaches can be modified and used for LCA in space? (Literature research)
- Is the LCA methodology suitable for assessment of impacts on space? What needs to be improved or added?
- How can the transition undergo from an earth focused LCA to an LCA including the space environment?

Results I: Literature Research : State of the art of ...

- Current impacts from space activities (Durrieu and Nelson 2013, Johnson 2010)
 - Satellites produce emissions from propellant use and material erosion. When they or other space objects enter earth atmosphere particles left over from sublimation change composition of the atmosphere.
 - Space debris is a danger for other space missions through collision or for nature and humans when it falls on earth.
- Space related LCAs: only few exist and they only cover impacts on the earth ecosystem.
 - ESA: LCA of launchers and complete space missions; ESA takes the first steps towards the design of "greener" space missions with its Clean Space Initiative and is working on a handbook for a methodology for LCA in the space sector. (Austin et al. 2015, Chanoine et al. 2015, ESA 2016)
 - NASA: LCA of ground activities only (Sydnor et al. 2011, Kocher and Sekura 2007)
 - LCA of an orbital launch rocket (Romaniw 2013)

- Regulations on space activities (United Nations 1967 and 1979, Kramer 2014)

International regulations such as the "Outer Space Treaty" or "Moon Treaty" established during the Cold War focus on the peaceful use of the space and/or the moon rather than on environmental issues.

- Regionalisation approaches (Acero et al. 2015, Hauschild and Potting 2005)

EDIP 2013 methodology is at this point the only suitable one for regionalization approaches, using additional site-dependent factors for most of the impact categories. However, only the concept of having specific factors for specific regions or objects (asteroids, planets) in space can be transferred into space considering different environmental conditions of each planet.

Results II: Suggestions for LCA methodology expansion

- To make LCA methodology suitable for space application it has to be expanded the following aspects have to be considered:
 - Set up of additional impact categories
 - Setting of system boundaries
 - Definition of space regions
 - New impact categories and reference units
 - Ethical challenges: human race versus potential extraterrestrial life
- According to the advancement of space exploration and travel, four LCA development phases are suggested: Earth-bound, Solar system-bound, Transition phase and Intergalactic. These phases mark different expansions of the system boundaries and will have to be developed as needed. The guiding principle, the top prioritization of the survival of the human race, was assumed as being indisputable and constant.

Table 1: Four development phases of LCA application in space

LCA DEVELOPMENT PHASE	ACTIVITY	GOAL	SYSTEM BOUNDARY	IMPACT CATEGORY
Earth-bound, now	Satellites in orbit around Earth	Preservation of human life on Earth	Earth, Earth's Exosphere	Current impact categories, space debris
Solar system-bound, 50 – 100 years	Missions in our solar system	Search for extra-terrestrial life, resource mining	Earth, other space objects	Extra-terrestrial life toxicity, space biodiversity
Transition phase 100 – 1,000 years	Missions in other solar systems, terraforming	Colonisation of other planets and space objects	Earth, other planets	Terraforming indicators
Intergalactic 1,000+ years	Interplanetary trade	Preservation of human life in the universe	Planet X, planet Y	Regionalized (current) impact categories

Outlook

- Methodology of LCA is flexible and capable to undergo adaptations for assessment of activities in space.
- Provided ideas and suggestions can be seen as a starting point of a discussion opening up many questions.
- More certainty about the development of space colonisation is indispensable for LCA development.

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