Harmonized space LCA data for efficient eco-design

A common eco-design basis for the European space industry

Johan Berg Pettersen* & Mario Amin Salgado Delgado *Assoc Professor, NTNU Industrial Ecology Programme johan.berg.pettersen@ntnu.no

Clean Space Industry Days 2018 ESA ESTEC, Noordwijk, 23-25 October





NTNU Industrial Ecology

and Technology

University of Science

Norwegian



cleansat

→ SPACE DEBRIS REDUCTION









→ REDUCING IMPACTS



cleansat

→ SPACE DEBRIS REDUCTION





Ecodesign & life cycle assessment

Ecodesign is designing products considering environmental impacts through the product life cycle.

Design with life cycle thinking.



http://www.learnlifecycle.com/





Ecodesign & life cycle assessment



Ecodesign is designing products considering environmental impacts through the product life cycle.

Design with life cycle thinking.



http://www.learnlifecycle.com/

Life cycle assessment (LCA) is the evaluation of environmental impacts through the life cycle of a product system.

Cradle-to-grave impacts.

- Compile emissions and resource uses
- Evaluate impact arising from these
- Interpret and use results



Ecodesign & life cycle assessment

Ecodesign is designing products considering environmental impacts through the product life cycle.

Design with life cycle thinking.



Life cycle assessment (LCA) is the evaluation of environmental impacts through the life cycle of a product system.

Cradle-to-grave impacts.

- Compile emissions and resource uses
- Evaluate impact arising from these
- Interpret and use results

Life cycle assessment provides the environmental information for ecodesign.



Development of LCA in ESA



> Before 2014: Early mapping of life cycle aspects: launcher etc

- Mainly relying on materials from non-space applications
- Examples: aluminium vs alloys, electronics, PVs...
- > Database projects ESA Space LCI database 2015 & 2017
 - LCA data for space: materials, manufacturing, components, propellants
- Specific evaluation of missions & activities 2017
 - Projects relying on space LCA database



Development of LCA in ESA



> Before 2014: Early mapping of life cycle aspects: launcher etc

- Mainly relying on materials from non-space applications
- Examples: aluminium vs alloys, electronics, PVs...
- Database projects ESA Space LCI database 2015 & 2017
 - LCA data for space: materials, manufacturing, components, propellants
- > Specific evaluation of missions & activities 2017
 - Projects relying on space LCA database

\checkmark Future projects should add to the database



Moving from technology projects completing LCA data...









NTNU

... to technology projects extending the LCA database





... to technology projects extending the LCA database







Starting point



ESA space LCA database

- Space LCI 2015: materials, manufacturing & components
- Space LCI 2017: propellants
- GreenSat 2018
 - Sentinel 3
 - Proba V



Screening process – Pedigree matrix





Scoring of datasets by *data quality indicator* (DQI) for revised database

- Technology representiveness
- Geographic representiveness
- Time representiveness
- Comprehensiveness & coverage
- Precision & uncertainty in data sources
- Methodology



Currently covered





- > 1 000 unique, space-specific elements
- Space materials & manufacturing processes
- Space propellants production
- Energy, logistics & waste treatments
- Space systems (components)
 - Electronics, batteries, PV systems, harness etc
 - Spacecraft equipment: propulsion, payload, stuctures
 - Tanks



Examples ESA - Spacecraft Equipment AOCS 13 Communication Antennas Electric Propulsion Tanks 40 Thruster 2 EPS 3 35 Batteries 25 PCDU 35 Solar array 25 Harness OBDH 2 Electronics 7 Payload 43 Satellite adapter 1 Structures 15 ESA space LCA 23 Structural elements **Thermal Control** 11 database ESA - Metals Aluminium AI 7000 alloys 5 Al Li alloys 6 Al per use 35 Al Si Mg Alloys 9 Not used Copper 5 Others 10 Powder production 2 Stainless steels 12 Titaniums 9 Tungsten



Currently covered









Gaps

- Surface treatment
 - Potentially critical, cf. Al anodizing
- Constantly new materials
 - Experience from GreenSat
- Propellants dominate impacts
 - E.g., Ariane 64, should be validated
- Spacecraft equipment
 - Complex systems with large variation
- Manufacturing
 - Additive manufacturing
 - Conventional manufacturing should be validated





General guideline

- ESA member representation, not country-specific
- Link to ESA database where relevant for «space» context
- Documentation: specify how data are made
 - Source & approach (specific vs. general, estimation or emprical)
 - Assumptions & calculations, with reasoning
 - Science = replication (can someone else follow and find same conclusion?)
 - Naming convention (really!)
 - Software & format of implementation, is MS Excel acceptable?
 - Uncertainty & variation necessary for decision support
- Data quality requirements & guideline for (non)acceptance in development



General guideline

- ESA member representation, not country-specific
- Link to ESA database where relevant for «space» context
- Documentation: specify how data are made

Solven
 As Golden rule of LCA
 Na YOU ARE MAKING DATA FOR SOMEONE ELSE TO USE
 So
 Uncertainty & variation necessary for decision support

• Data quality requirements & guideline for (non)acceptance in development



Challenges for further expansion



- Generalizing sensitive data
- Large portfolio of materials used for space
- Significant variation between components & missions
- Surface treatment & manufacturing vs material inputs (bill-of-material paradox)
- Spacecraft equipment a large category



Comparison of two reaction wheels



Reaction wheel #1
Reaction wheel #2



Comparison of two reaction wheels – the simple LCA

1 kg Reaction Wheels #1



Electronit Unit - Low IC

ESA Samarium cobalt magnet, RER U

Aluminium generic part surface treatments, DE

Stainless steel part surface treatments, DE

■ Aluminium generic part with generic process sequence, DE

■ Stainless steel part with generic process sequence, DE



 \square N

Comparison of two reaction wheels – the complex LCA



Tetrafluoroethylene {GLO}| market for | APOS, U

- Stainless steel 440b (X 90 CrMoV 18) alloy {RER} | production | Alloc Def, U
- Printed wiring board, surface mounted, unspecified, Pb containing {GLO}| market for | Alloc Def, U_PCB PROBA V_epoxy
- Ferrite {GLO}| market for | APOS, U
- Tin plating, pieces {GLO}| market for | APOS, U
- Copper {GLO} | market for | APOS, U
- Shielded jacketed single wire [mass], AWG 26 {GLO}| production | Alloc Def, U
- Titanium, primary {GLO}| market for | APOS, U
- Iron-nickel-chromium alloy {GLO}| market for | APOS, U
- Shielded jacketed single wire [mass], AWG 20 {GLO}| production | Alloc Def, U
- Single wire [mass], AWG 20 {GLO}| production | Alloc Def, U
- Cast iron {GLO} | market for | APOS, U
- Steel, low-alloyed {GLO}| market for | APOS, U
- Glass tube, borosilicate {GLO} | market for | APOS, U
- Polyethylene terephthalate, granulate, amorphous {GLO}| market for | APOS, U
- Polyvinylfluoride {GLO}| market for | APOS, U
- Cobalt {GLO}| market for | APOS, U
- Samarium europium gadolinium concentrate, 94% rare earth oxide {GLO}| market for | APOS, U
- Stainless steel 304 alloy {RER} | production | Alloc Def, U
- Polyurethane, flexible foam {GLO}| market for | APOS, U
- Polyetherimide (PEI) {RER} | production | Alloc Def, U
- GFRP, Autoclave process {RER} | production | Alloc Def, U
- Adhesive, for metal {GLO}| market for | APOS, U
- Polyurethane, flexible foam {GLO}| market for | APOS, U
- Solder, paste, Sn63Pb37, for electronics industry {GLO}| market for | APOS, U
- Solder, bar, Sn63Pb37, for electronics industry {GLO}| market for | APOS, U
- Aluminium, AA 6082 {RER} billet production | Alloc Def, U
- Stainless steel 431 (X17CrNi16-2) alloy {RER} | production | Alloc Def, U
- Stainless steel 440b (X 90 CrMoV 18) alloy {RER} | production | Alloc Def, U



Comparison of two reaction wheels



Reaction wheel #1
Reaction wheel #2



Harmonized space LCA data for efficient eco-design

A common basis to support ecodesign for space systems

Johan Berg Pettersen* & Mario Amin Salgado Delgado

*Assoc Professor, NTNU Industrial Ecology johan.berg.pettersen@ntnu.no

Clean Space Industry Days 2018 ESA ESTEC, Noordwijk, 23-25 October



