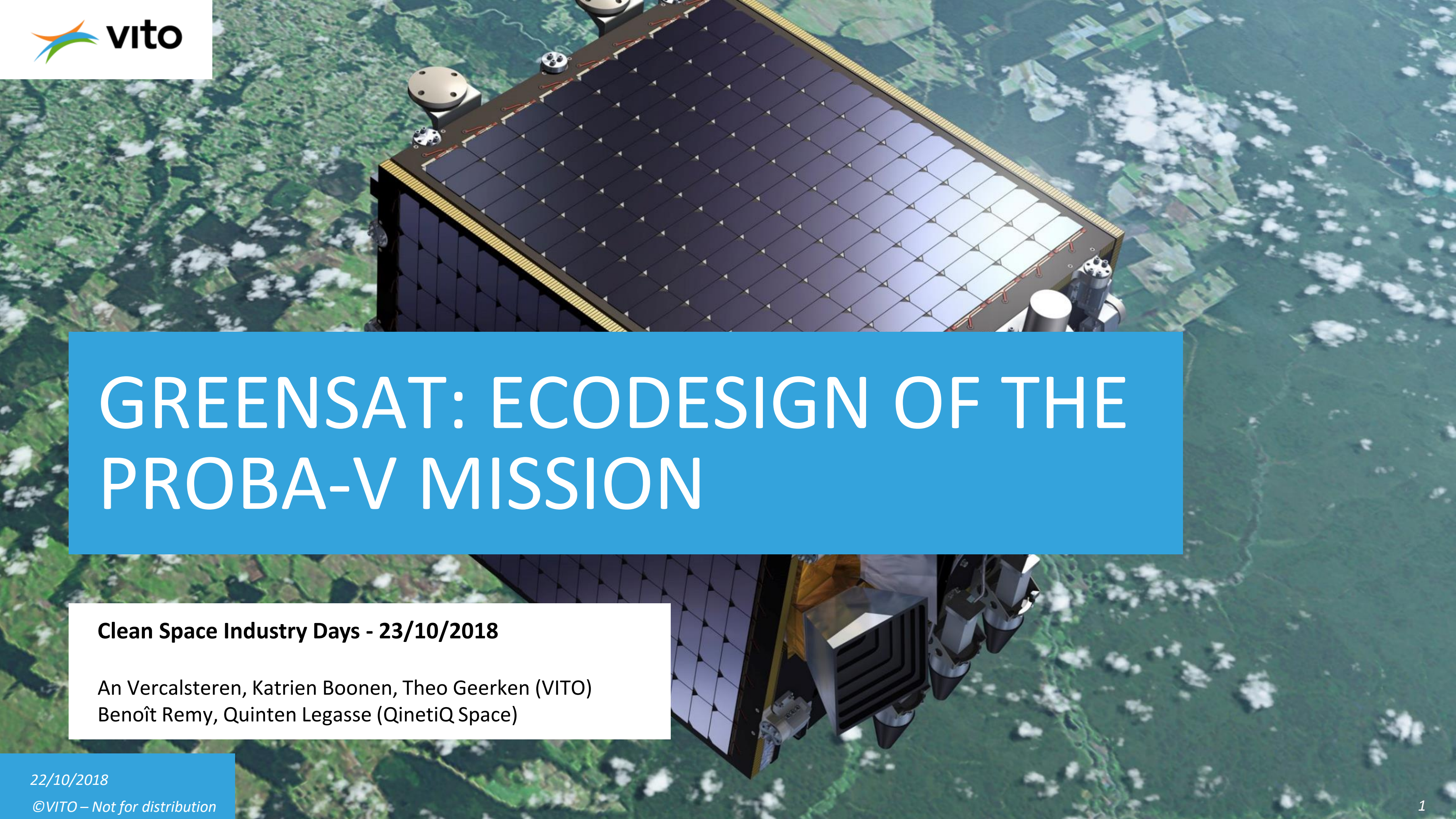


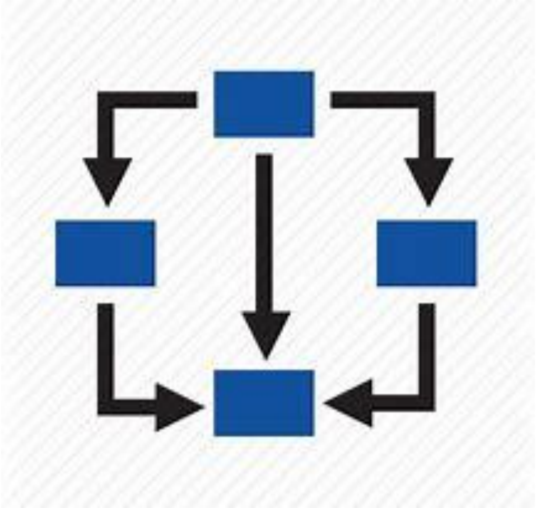
GREENSAT: ECODESIGN OF THE PROBA-V MISSION

Clean Space Industry Days - 23/10/2018

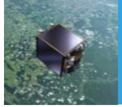
An Vercalsteren, Katrien Boonen, Theo Geerken (VITO)
Benoît Remy, Quinten Legasse (QinetiQ Space)

OUTLINE

- Introduction and approach
- Life Cycle Assessment of PROBA-V
- Selection of ecodesign options
- Next steps



INTRODUCTION AND APPROACH



GREENSAT PROJECT

- **Focus:**
  - from **assessment** to **reduction** of environmental impact
  - through **redesign** of an existing satellite mission
  - understand how the mission specifications should be (re-) formulated

- **Overall objectives:**
  - to redesign a space mission
    - based on ecodesign principles
    - reducing at least 3 environmental impact categories by 50%, without an increase to others
  - to assess if space sector is ready to evolve into next step – redesign of space mission aiming to reduce environmental impact

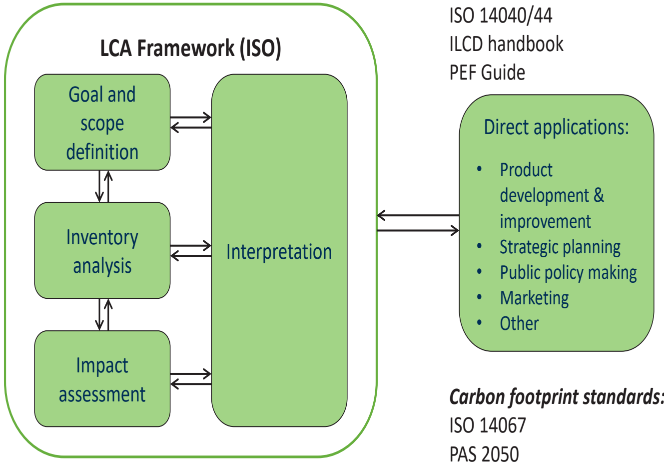
GREENSAT PROJECT

- **Specific objectives:**
  - Identify relevant design improvement options, leading to at least a 50% environmental impact reduction on at least three impacts
  - Use and test Space system LCA-guidelines and ESA LCI/LCA database
  - Identify potential benefits and difficulties of performing and implementing ecodesign in European space sector
  - Communicate on results (a.o. through infographics)

- **Four work packages:**
  - WP1: Develop the LCA model of the space mission study case and identify hot spots
  - WP2: Identification of ecodesign options – brainstorm and tradeoff
  - WP3: Ecodesign preliminary concept development and LCA
  - WP4: Quantitative comparison of ecodesign options

LCA OF PROBA-V

General standards:
ISO 14040/44
ILCD handbook
PEF Guide

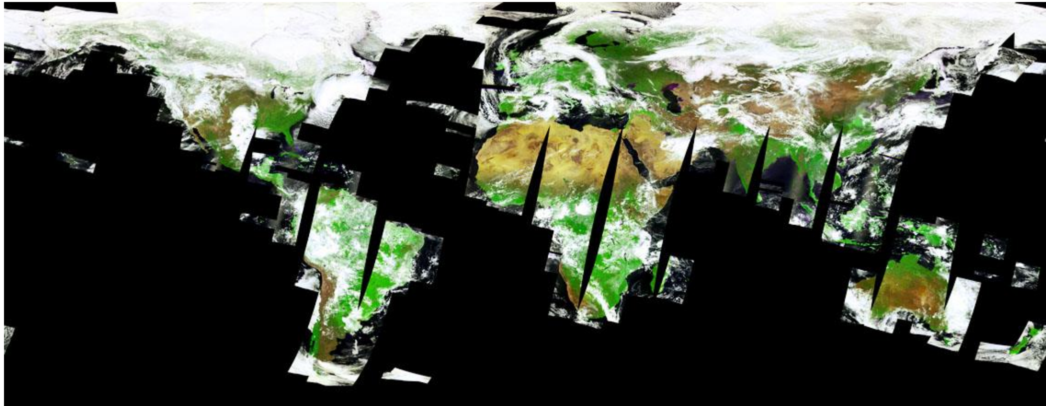


Carbon footprint standards:
ISO 14067
PAS 2050
GHG Protocol Product Standard

SUBJECT: PROBA-V

- **Mission objective -** Gap filler mission for SPOT-Vegetation and Sentinel-3

- **Project duration:** 3,5 years
  - **Start of Phase B1:** January 2009
  - **Launch:** May 2013 on-board Vega VV02 from Kourou



GOAL AND SCOPE

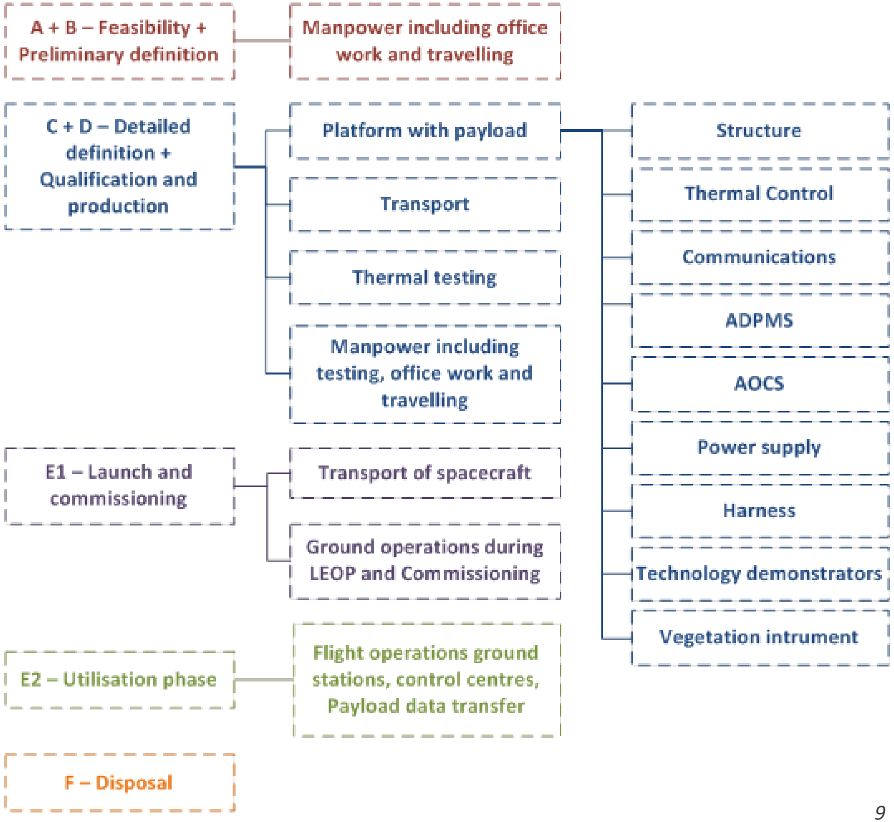
- **GOAL**:
  - to identify environmental **hot spots** of the PROBA-V mission
    → which is an important starting point to look for ecodesign options
  - to quantify the environmental impact of the PROBA-V mission, to understand the impacts and the sources
    → which is a **baseline to benchmark** the environmental impact of the ecodesigned Greensat mission and which allows to assess the environmental impact reduction

- **SCOPE:**
  - **Payload**:
    - Vegetation Instrument (VGT-P)
    - 5 technology demonstrators
  - **Ground segment:**
    - mission control centre (MCC) at ground station in Redu, Belgium
    - additional ground stations such as Kiruna, Inuvik, and Fairbanks
    - user segment operated by VITO in Mol, Belgium

- **Functional unit:** Conform space system LCA guidelines
  "one space mission in fulfilment of the mission's requirements"

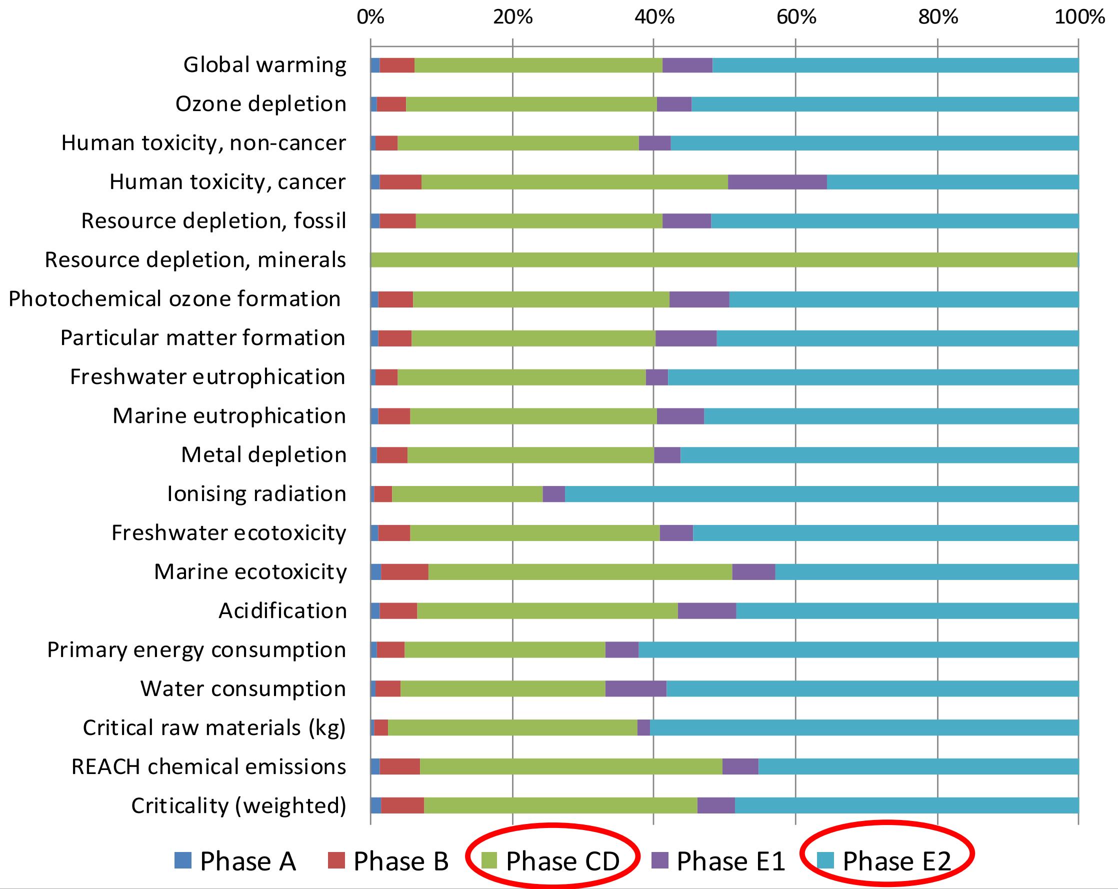
SYSTEM BOUNDARIES

- ✓ Space segment:
  - PROBA-V platform with Vegetation instrument and technology demonstration payloads
- ✓ Launch segment:
  - Placing the PROBA-V satellite into the selected orbit
  - Launch is excluded
- ✓ Ground segment:
  - Controlling and monitoring the satellite
  - Archiving the Vegetation instrument data at Level 0
  - Including the user segment for processing the forwarded Level 0 data up to Level 3

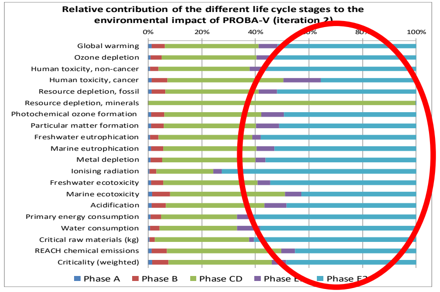


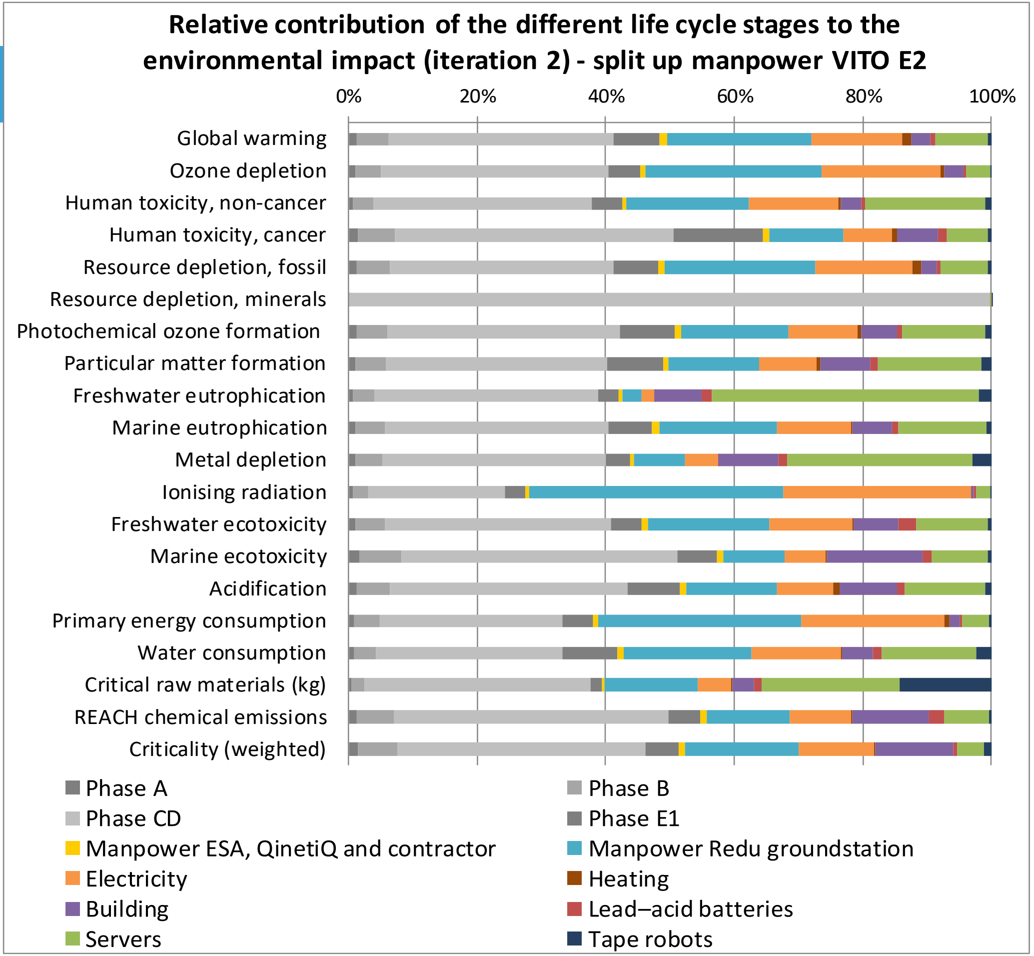
IDENTIFICATION OF HOTSPOTS

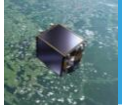
Relative contribution of the different life cycle stages to the environmental impact of PROBA-V (iteration 2)



IDENTIFICATION OF HOTSPOTS

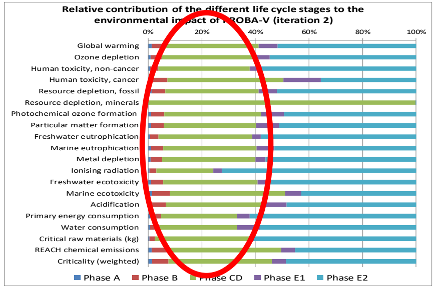


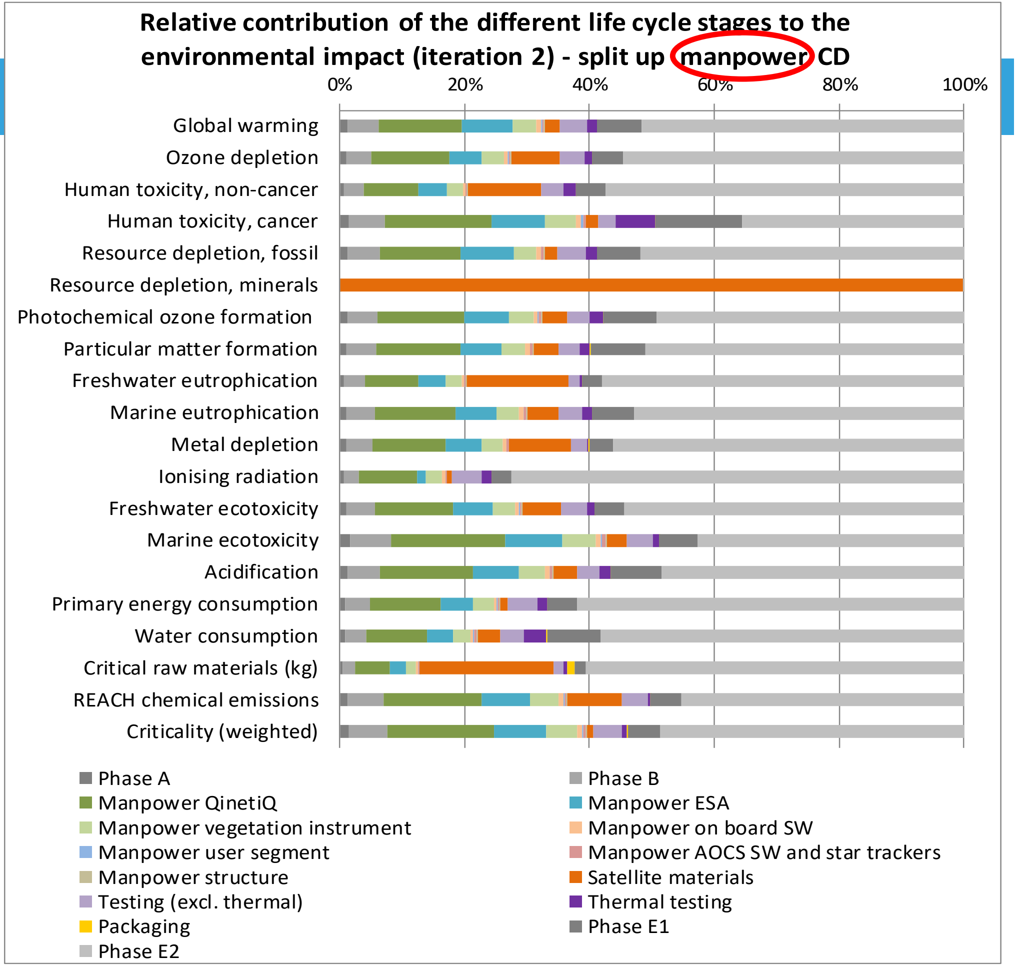


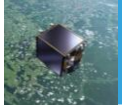


LCA OF PROBA-V

IDENTIFICATION OF HOTSPOTS



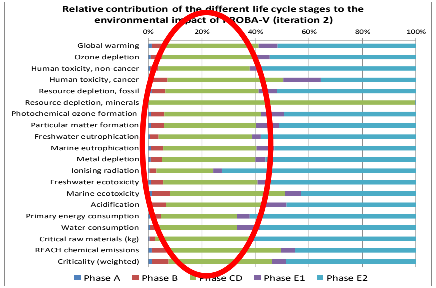


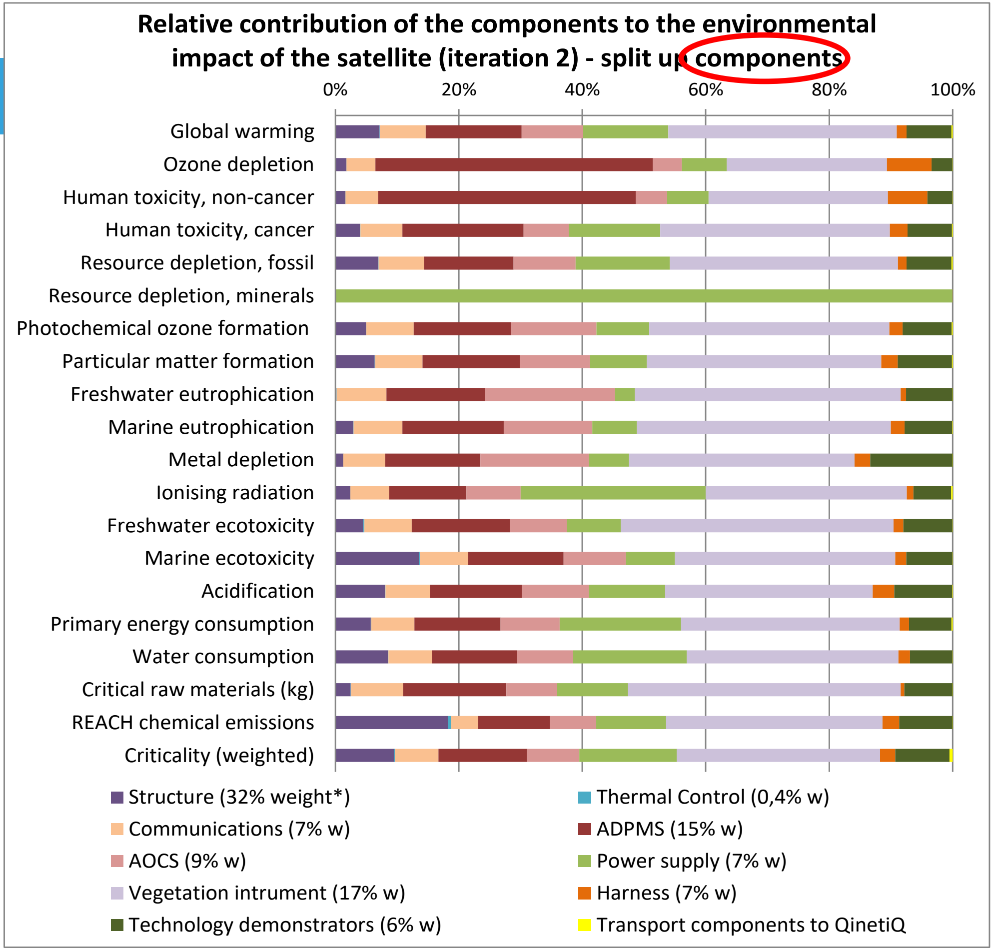


LCA OF PROBA-V

IDENTIFICATION OF HOTSPOTS

Breakdown of phase CD satellite materials (all models included) into the different components
**weight percentage based on total mass including test models*

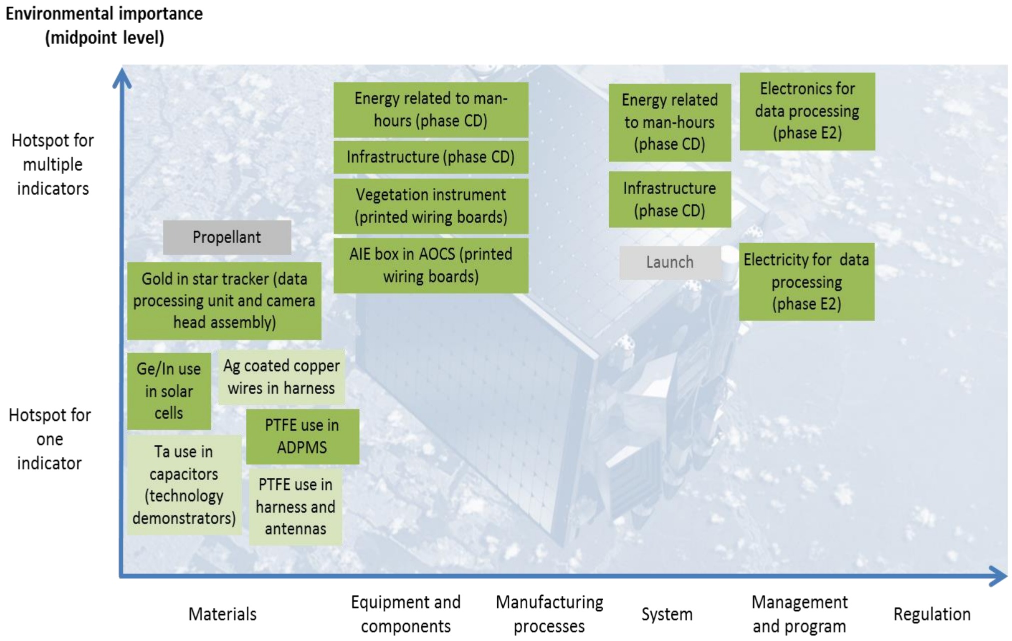




IDENTIFIED HOTSPOTS

Environmental hot spots for the PROBA-V are identified for **different levels**:

- Materials
- Equipment and components
- Manufacturing processes
- System
- Management and programmatic issues
- Regulation



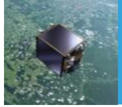
Impact category	Phase A	Phase B	Manp. QinetiQ - CD	Manp. ESA - CD	Manp. veget. instr.	Other manp. CD[1]	ADPMS	AOCS	Power supply	Veget. instr.	Other comp.[2]	Transp. comp., packag.	Testing	Phase E1	Manp. ESA,RSS, QinetiQ	Electr. (VITO)	Heating (VITO)	Building (VITO)	Batter. (VITO)	Servers (VITO)	Tape robots (VITO)
Global warming			Electricity use for office work and production of infrastructure		+ heating					PCB production			Electricity use testing, infrastructure, for thermal testing: production of nitrogen and transport of the satellite to the testing facility	Electricity use for office work, production of infrastructure, travel	Redu groundstation - electricity use	el. natural gas, coal		energy for materials		energy produc-tion processes	
Ozone depletion							HCFC-22, CFC-12 em. PTFE									nuclear (uranium product.)		cable waste treatment			
Human toxicity, non-cancer							CFC-10 em. PTFE wires			CFC-10 em. PTFE						el. waste incinerat.		copper scrap treatment		dipropylene glycol monomethyl ether for PCB	
Human toxicity, cancer					+ travel (formalde-hyde emissions)											el. wood and waste		formalde-hyde em. clay bricks		formaldehyde em. mounting	
Resource depletion, fossil					+ heating											electricity fossil fuel				fossil fuel production processes	
Resource depletion, minerals									Ge, In in solar cells												
Photochemical ozone formation																electr. from coal, waste, wood		em. copper extraction (NOx)		PCB: em. gold extract. (NOx)	
Particulate matter formation																		emissions copper pro-duction		em. fossil energy (PM2.5)	
Freshwater eutrophication							gold PCB (sulfidic tailings)	gold star tracker and PCB		gold (sulfidic tailings)	gold PCB (sulfidic tailings)									gold PCB (sulfidic tailings)	
Marine eutrophication																nuclear (uranium mining)					
Metal depletion										gold						el. blast furnace gas		copper		gold, Sn in PCB	Cr in steel casing
Ionising radiation																nuclear power					
Freshwater ecotoxicity										methyl acrylate em.						bio-based power		Cu scrap treatment	electrode product.	PCB (soy-based phen-olic resin)	
Marine ecotoxicity																emissions el. coal		Cu (sulfidic tailings)		gold PCB (sulfidic tailings)	
Acidification																el. coal and waste		emissions Cu product.		energy produc-tion processes	
Primary energy consumption					+ heating											nuclear (uranium)					
Water consumption																hydro-power		hydro-power		hydro-power	
Critical raw materials (kg)							Tungsten in PCB			tungsten	tungsten in PCB					el. waste incinerat.		Cr in steel		Cr in steel casing	Cr in steel casing
REACH chemical emissions										gold (arsenic em. tail.)	PEI (1,2-dichloroethane em.)					Cu cables (em. tail.)		Cu (arsenic em. tail.)		gold (arsenic em. tail.)	
Criticality (weighted)																el. blast furnace gas		clay, gravel in bricks		Fe, Cr in steel casing	

Color scales: dark red: > 50% of the impact in a specific category is due to the item, dark orange: 25 - 50%, light orange: 10 - 25%, yellow: 2,5 to 10%. Boxes with wide, colored borders indicate common causes of environmental impact over different impact categories and/or contributors.

SELECTION OF ECODESIGN OPTIONS

IDENTIFICATION OF ECODESIGN OPTIONS

- Starting from **environmental hotspots**
- **Two-step approach**:
  - *External workshop*, with wider group of stakeholders
  - *Internal brainstorm*, with experts specifically involved in the PROBA-V life cycle stages
- **Selection process** applied to long list of ecodesign options generated for space missions in general and PROBA-V in particular



SELECTION OF ECODESIGN OPTIONS

Step 0: Definition of ecodesign options

- Grouping of ideas from brainstorm and workshop in ecodesign options
- Identifying options relevant for PROBA-V

Step 1: AHP trade-off

- Based on AHP methodology
- Based on set of criteria (effort, duration, risk, impact, environmental impact, reusability, space relevance)
- Expert judgement

Step 2: Semi-quantitative assessment

- Semi-quantitative analysis of maximum reduction potential

Step 3: Quantitative assessment

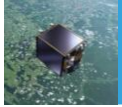
- Quantitative (screening) analysis of reduction potential incl. burden shifting

70+ options → 25 options → 10 options → 6 options

STEP 1: AHP TRADE OFF

- To select the **25 most promising options** out of the long list
- AHP trade-off based on the following **criteria**:
  - Solution implementation effort (cost, manhours, means)
  - Duration (time to market/launch)
  - Risk (feasibility, applicability, performance, availability of alternatives, flexibility)
  - Impact (operational cost)
  - Overall environmental impact
  - Reusability of the solution
  - Additional to identify the options that are ‘space specific.

	Option	Level	A	B	C	D	E	F	Score (%)	Spa spec (ES
1	Not using PTFE but e.g. PE instead	1	5	5	5	3	5	4	92,1	x
2	Promote teleworking, use of teleconferencing	4	5	5	4,5	3	4	5	88,0	
3	More efficient on-ground data management	2	4	3	5	4	5	4	86,9	x
4	Use of long-heritage components	4	5	5	4	2	5	4	86,4	x
5	Use recycled Germanium	3	4	4	4	3	5	5	86,3	x
6	More efforts in early phases	5	4	4	4	3	5	5	86,3	
7	Green propellants	1	4	4	4	4	5	4	85,6	x
8	Reduce copper surface to be Ag coated	1	5	4	4	5	3	5	83,5	x
9	Flexible design	4	4	4	4	2,75	5	4	82,6	x
10	Renewable energy	4	4	3	4	3	5	4	81,2	
11	Reduce documentation	5	5	4	4	3	4	4	81,2	
12	Improve the efficiency of buildings	4	4	4	5	3	4	4	81,0	
13	System-level testing	4	4,5	5	3,5	3	4	4	79,8	x
14	Use of modular buildings for ground stations	4	4	5	4	3	4	4	79,6	
15	Recurrent platforms	4	4	3	4	3	5	3,5	79,6	x
16	Use of modular components	2	4	3	5	3	4	4	78,9	x
17	Si instead of Ge	1	4	5	5	1	4	4	78,2	x
18	Prolong electronics lifetime	2	3	4	4	3	5	3,5	78,1	x
19	Adopt PMI best practices and focus more on risk management	5	5	4	5	3	3	3,5	77,4	x
20	Laser/plasma surface treatment	3	4	5	5	3	3	4	77,4	x
21	More on-board and on-ground autonomy	4	3	3	4	3,5	5	3,5	77,3	x
22	Reduce components qualification requirements	2	5	3	2	3,5	4	5	76,8	x
23	Optimize electronics	2	4	4	3	4	4	4	76,7	x
24	Reduce number of design iterations	5	5	4	3	2,5	4	4	76,7	x
25	Heat pipes	2	3	4	3,5	3	5	3,5	76,4	x
26	Virtual thermal testing	2	3,5	3	3	3	5	4	76,1	x



STEP 2 AND 3: (SEMI-) QUANTITATIVE ASSESSMENT

- **Step 2:**
  - To assess **potential reduction** of each ecodesign option specifically on the satellite's hot spots, which leads to a further selection of 10 options

- **Step 3:**
  - To assess **additional effort** needed to achieve a specific option (e.g. additional testing, software development, different materials, weight increase) is calculated
  - Including system level impacts
  - Orders of magnitude

FINAL SELECTON OF ECODESIGN OPTIONS

- Following **ecodesign options** are selected to further elaborate:
  - Using alternatives for PTFE
  - More efficient on-ground data management incl. prolonging life span of on-ground electronics
  - Use recycled Germanium and its production as a by-product of the extraction of other metals for solar panels
  - System-level testing incl. virtual thermal testing methods
  - More on-board versus on-ground autonomy
  - Optimize electronics

- Including different levels and both space specific as well as more generic or groundstation related options

NEXT STEPS

PRELIMINARY CONCEPT DEVELOPMENT

1. **Further development and design of selected ecodesign options**
   - In close cooperation with external consultants (suppliers, …)
   - On different levels → evaluation of full consequences

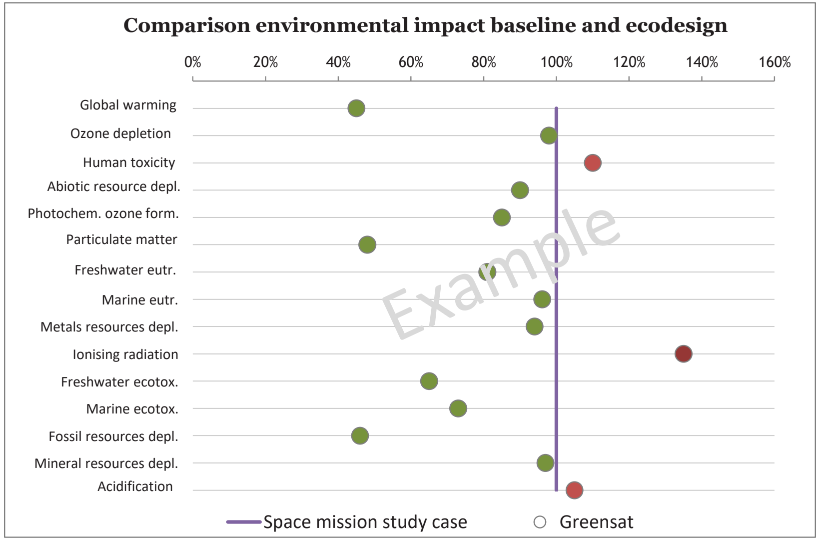
2. **Iterative LCA on individual option level to guide design process**
   - Avoid burden shifting
   - Max. 3 LCA-iterations per ecodesign option

3. **LCA comparing ecodesign option with baseline on option level**
   - Identification of environmental indicators that are significantly reduced

QUANTITATIVE COMPARISON OF ECODESIGN OPTIONS

1. **LCA of Greensat PROBA-V mission incorporating all ecodesign options**

2. **Compare environmental impact of baseline and redesign on space mission level**
   - To identify environmental saving
   - To check feasibility of project objective (50% reduction for 3 environmental impacts)



QUANTITATIVE COMPARISON OF ECODESIGN OPTIONS

4. **Assessment of cost of environmental saving**
   - Monetization method to translate and weight environmental impacts in 1 indicator
5. **Assessment of cost, performance, risk, schedule and feasibility**
6. **Develop summarizing table with pros and cons of ecodesign options**
7. **Develop roadmap for 3 selected options**
8. **Revisit missions specification**

CONTACT DETAILS

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