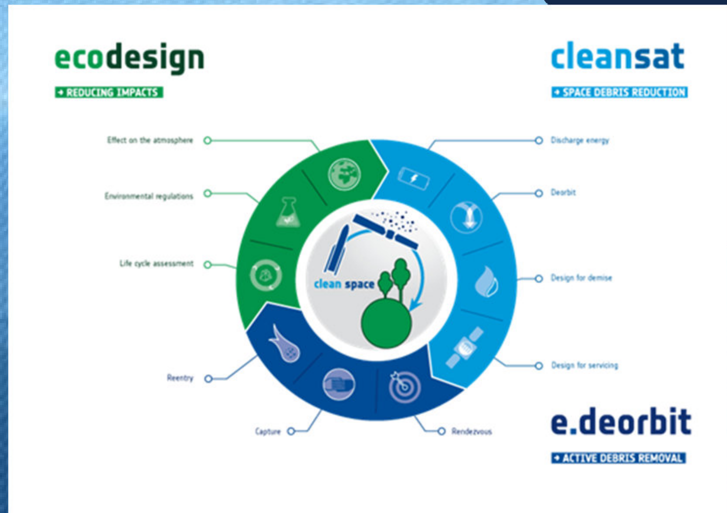
LCA Ground Segment
CSID Conference 2021

ESA Contract No. 4000123991/18/NL/GLC/as
Ground Segment Life Cycle Assessment – Methodological and Quantitative



esa

21th September 2021

RINA

CT ingenierie

deimos elecnor group

Project Introduction

Main Objective:

- **Assess the environmental performances** and the applicability of **eco-design** principles to **Ground Segment** through the elaboration of a **specific methodology**, the involvement of ground segment experts and the in depth evaluation of the most promising options
- All the “constituting blocks” of the ground segment will be evaluated: infrastructure, RF equipment, personnel, etc.

- This can be obtained though:
  - Expertise in ground segment
  - Expertise in LCA
  - Expertise in eco-design

Project Introduction

Main Objectives:

- **Identify and define various “generic families” of Ground Segment (GS)** representatives for Telecommunication (TC), Navigation (NAV), Scientific, Earth Observation (EO), etc. missions, covering their specific infrastructures and operations
- **Perform Life Cycle Assessment** (LCA) of the environmental impact of the various GS families
- **Provide data sets and methodological guidelines about LCA methodology** applied to GS in order to update/complete the ESA LCA Handbook and Database.
- **Investigate innovative eco-design options** (technical solutions, spin-ins and/or new technologies, innovative processes, etc.) by also considering non-technical aspects (cost and risks, TRL, implementation roadmap, etc.) which can be applied to the various GS family’s infrastructures and operations in order to reduce their environmental impact

Task 1 – Overview of different Ground Segment for different mission types

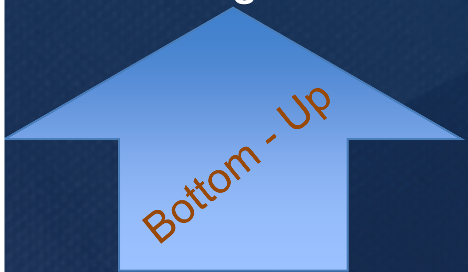
Task1 approach: sequential analysis following a three steps approach:

- **Subtask 1.1: Identification of different Ground Segments**
- **Subtask 1.2: Grouping of Ground Segments**
- **Subtask 1.3: Identification of main elements / subsystems**

Main output of Task1 is the consolidation of GS LCA families

To GS major

Building Blocks



From Mission

From GS

Building blocks

To Equipment

Task 1 – Overview of different Ground Segment for different mission types

Task 1.1 – Identification of different ground segments

- **Inputs**: Survey of more than twenty ESA / non-ESA missions
- **Process**: Identification of **Ground Segment "Major" Building Blocks**
- **Outputs:** Four (4) major components identified ✓

Mission Family	GS	MOC	SOC
Science	X	X	X
Navigation	X	X	
Earth Observation	X	X	X
Communications	X	X	
CubeSat	X	X	

MOC: Mission Operations Centre

SOC: Science Operations Centre

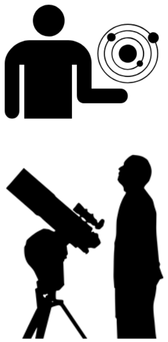
DPC: Data Processing Centre

Ground Station (GS)

Task 1 – Overview of different GS for different mission types

Task 1.2 – Grouping of ground segments

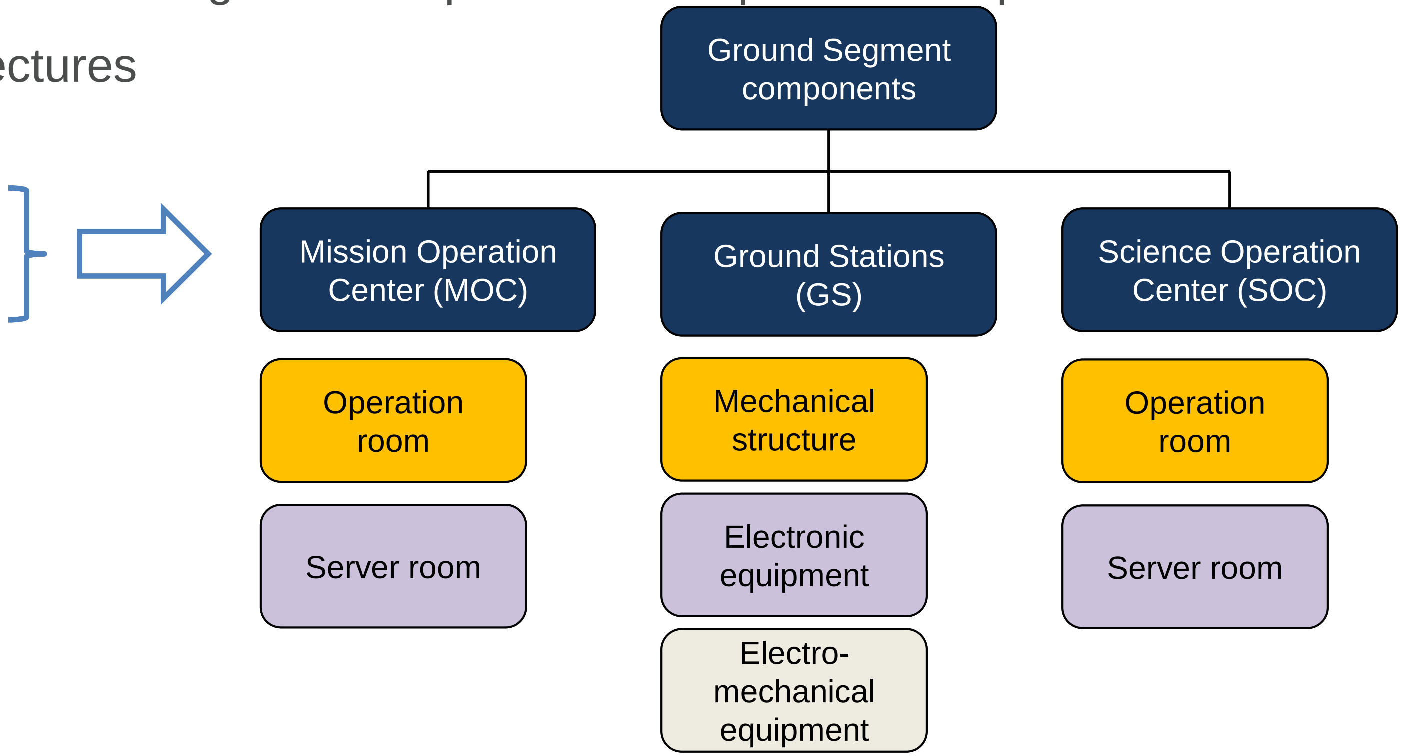
- **Inputs**: Major Ground Segment components from previous step as well as its top level architectures



GSs

MOCs

SOCs



- **Process:** Identification of commonalities among major GS Components

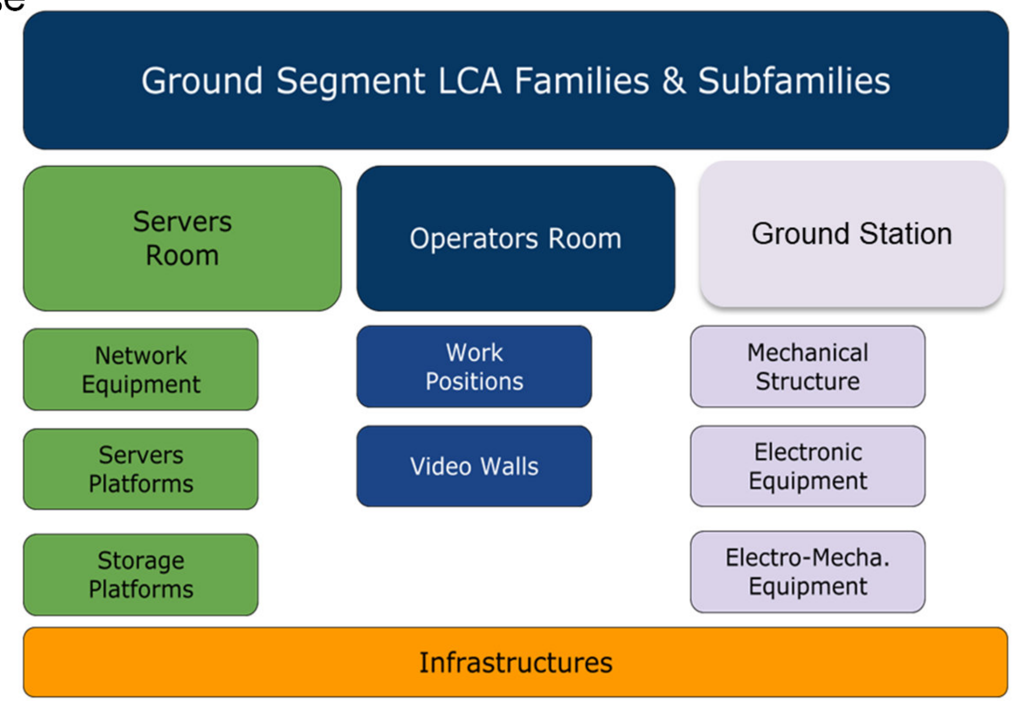
Task 1 – Overview of different Ground Segment for different mission types

Task 1.2 – Grouping of ground segments

- **Output**: Consolidation of the LCA families and **sub-families.** Four (4) major building blocks and its sub-families consolidated.

Infrastructures (Development phase Maintenance and Operation):

- Server Room (MOC/SOC)
- Operator Room (MOC/SOC)
- Ground Station



Task 1 – Overview of different Ground Segment for different mission types

Task 1.3 – Identification of main elements and subsystems

- **Inputs**: Eleven (11) study cases covering the complete range of missions types

Missions TYPE	Facility NAME	Location / Country	Facility TYPE	Study Case	PoC
Science	ESTRACK, CEBREROS	Avila, SP	Ground Station, DSA2	Gaia	Lionel Hernandez - CEB Station manager lionel.hernandez@esa.int
	ESAC	Villanueva de la Cañada, SP	Data Processing Center (DPC)		
Navigation	ESTRACK, ESEC	Redu, Belgium	TTC / IOT Ground Station	Galileo	Benoit Demelenne – Chef des Operations benoit.demelenne@esa.int
Earth Observation	ESTRACK, KIRUNA	Kiruna, SW	Ground Station, KIR-1 and KIR-2	Sentinel-1A	Anders Paajarvi - KIR Station manager anders.paajarvi@esa.int
	Deimos DCM	Puertollano, SP	Ground Station Operations Control Center (OCC)	Deimos-2	Antonio Ramírez - PL1 Station manager antonio.ramirez@deimos-space.com
Communications	HISPASAT	Arganda del Rey, SP	Ground Station Operations Control Center (OCC)		Pedro L. Molinero plmolinero@hispasat.es
NanoSat market	LEAF SPACE	Puertollano, SP	(Hosted) Ground Station	New Space	Jonata Puglia jonata.puglia@leaf.space
Many	ESOC	Darmstadt, GE	Operations Control Center (OCC)		Trough LCA Project
SST	DeSS	Puertollano, SP	Space Surveillance Optical Site		Antonio Ramírez - PL1 Station manager antonio.ramirez@deimos-space.com

Task 2 & 3 – LCA of Ground Segment

Task 2 is related to the LCA activities, applied to Ground Segment, used for the management of different space missions

The main activities are:

- LCA of different Ground Segment Families, identified in Task1
- Elaboration of methodological guidelines, in line with Space System LCA guidelines (ESA, 2016)
- Providing of datasets of main elements constituting Ground Segment
- Identification of hotspots

This approach is firstly applied in Task2 and then re-iterated and finalised in Task3

Task 2 & 3 – LCA Report

LCA of different Ground Segment families

Method approach:

The LCA study has been implemented creating and then assessing two main dataset typologies: «Maintenance & Operation» (M&O) and «Ground Systems» due to the specific architectural Ground Segment features.

- **Maintenance & Operation:** focused on the operational facilities (GSs, MOCs, SOC/DPCs) activities consumptions.
- **Ground systems (equipment)**: focused on the manufacturing processes (development phase) of the different Ground Segment.

M&O impact assessment + Mission required efforts → Mission impact assessment.

Task 2 & 3 – LCA of Ground Segment

LCI of different Ground Segment families: Operation → Ground Stations, Mission Operation Centres, Science Operation Centre, Data Processing Centre

Example: DEIMOS GS Yearly Consumption Data

Table 1.1: Deimos Puertollano Ground Terminal operational consumptions data

Dataset Name	Deimos Puertollano Ground Terminal operation (EO Mission – non ESA mission)		
Description	1 year of Ground Station operation		
Source	Deimos		
Relevance	No ESA Space Missions – Earth Observation		
FU	1	Year	
Name	**Quantity**	**Units**	**Life Cycle inventory**
Material Inputs			
Electricity consumption	721,3	kWh	Europe: market group for electricity, medium voltage
Water consumption	N/A	kg	Europe without Switzerland: market for tap water
Gas/Oil consumption	N/A	MJ	Europe: Heat production, natural gas, at boiler atmospheric non-modulating <100kW
Diesel consumption	N/A	kg	Europe: diesel production, low-sulfur
Lubricant	46,47	kg	RER: lubricating oil production
Paper consumption	N/A	kg	Europe: Paper production, woodfree, uncoated, 50% recycled content, at non-integrated mill
Waste produced			
Municipal waste	0	kg	RoW: market for municipal solid waste ecoinvent
Hazardous waste	0	kg	Europe without Switzerland: market for hazardous waste, for incineration ecoinvent 3.5

Task 2 & 3 – LCA of Ground Segment

LCI of different Ground Segment families: Equipment → following firstly DEIMOS and then ESOC structure

Example: Storage Platform LCI

Table 2.180: Storage platform model breakdown

Description		1 kg of Storage platform at the output gate		
Source		Deimos		
Relevance		All		
FU		1	kg	
Reference weight		248	kg	
Name	**Breakdown**	**Quantity**	**Units**	**Life cycle inventory**
Material inputs				
Casing - Stainless Steel	49%	0,49	kg/FU	ESA Stainless steel product
Plastic, Polypropylene (PP)	3%	0,03	kg/FU	RER: polypropylene production, granulate ecoinvent 3.5
Casing - Aluminium	8%	0,08	kg/FU	ESA Stainless steel product
Electronic unit - Memory type	27%	0,27	kg/FU	Electronic unit, High IC, memory type
Electronic unit – Low IC	13%	0,13	kg/FU	Electronic unit, low IC
Manufacturing processes				
Extrusion	/	0,03	kg/FU	Extrusion of plastic sheets and thermoforming, inline, GLO

Task 2 & 3 – LCA of Ground Segment

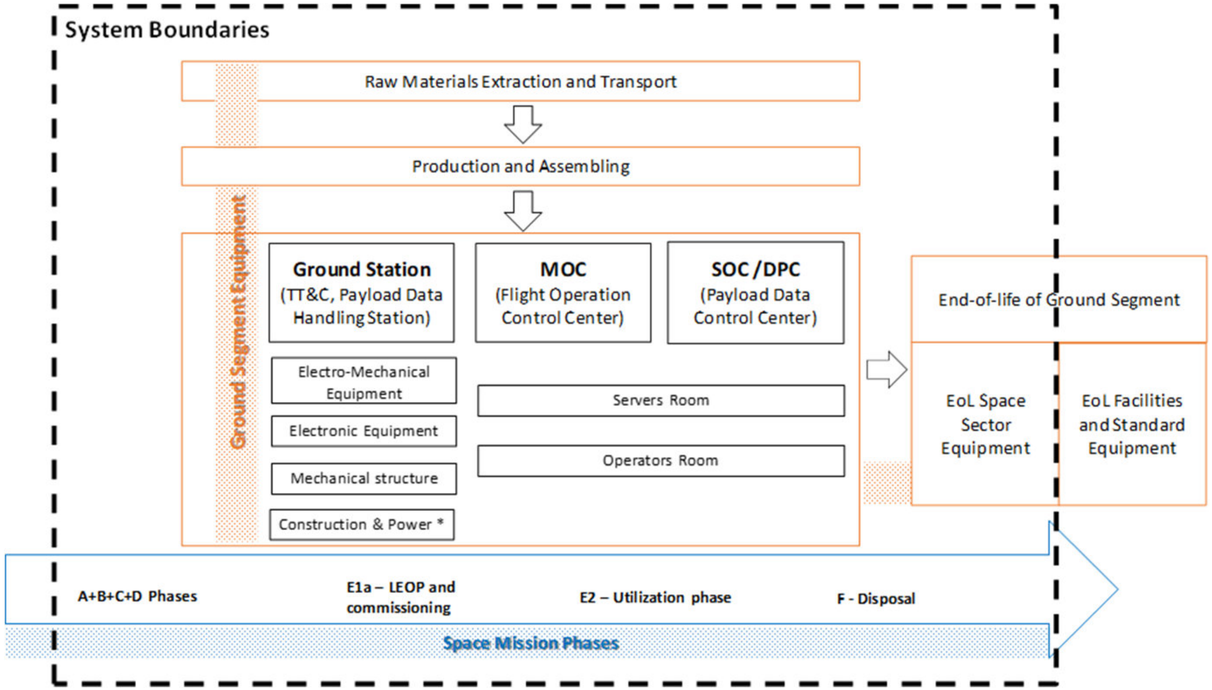
- <u>Functional Unit:</u>

Fulfilment of requirements of Ground Segment for the entire mission, along its lifetime.

The fulfilment shall include the operation of Earth Observation / Science / Telecommunication / Navigation / CubeSat mission, along its lifetime and any Ground Segment adaptation required for the specific needs of the mission.

- <u>System Boundaries:</u>

✓ Space Mission Oriented
✓ Assets Oriented



Task 2 & 3 – LCA of Ground Segment

List of the Ground Segment facilities grouped by the mission family

Mission Family	Mission NAME	Mission Operations Centre (MOC)	Science/Data Processing Centre (SOC/DPC)	Ground Station(s)	Note
Earth Observation	Deimos 2 (non-ESA mission)	Deimos MOC (Puertollano), SP	N/A	- Deimos PL01 (Puertollano), SP - Kiruna, SW - Svalbard, NW	Kiruna, Svalbard assumed similar to PL01. (Not Kiruna/Svalbard related to ESTRACK, but managed by SSC)
	Sentinel 3	ESOC (Darmstadt), GE	ESRIN (Fucino), IT	- Kiruna, SW - Svalbard,NW; - Troll, NW	Svalbard and Troll are assumed similar to Kiruna.
Navigation*	Galileo	N/A	N/A	N/A	/
Science	GAIA	ESOC (Darmstadt), GE	ESAC (Villafranca), SP	- Cebreros, SP - Malargue, AR - New Norcia, AU	Malargue, New Norcia are assumed similar to Cebreros.
CubeSat	Leaf Space	Deimos MOC (Puertollano), SP	N/A	- Deimos PL02 (Puertollano), SP	/
Communications	Hispasat 35W	Hispasat MOC (Arganda del Rey), SP	N/A	- Hispasat (Arganda del Rey), SP	/

Task 2 & 3 – LCA of Ground Segment

Facilities (GSs, MOCs, SOCs):

a) LCIA based on the yearly consumption;
b) LCIA focused on the sources of impacts based on the yearly consumption;
c) LCIA based on 1 hour (GSs) and 1 man-day (MOCs, SOCs).

Ground system:

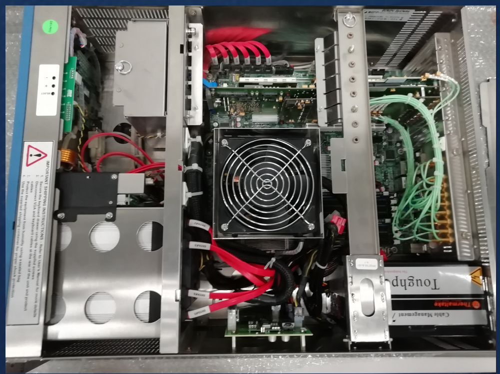
a) LCIA of the Deimos Puertollano (MOC & GS);
b) LCIA of Kiruna (Kir-1) 15m GS;
c) LCIA of Cebreros (CEB) 35m GS;
d) Ground System Equipment (170 items).

Missions LCIA:

a) Deimos 2;
b) LeafSpace;
c) Hispasat 36W;
d) Sentinel 3A,
e) Gaia.

Task 2 & 3 - Life cycle impact assessment – Development phase

- Ground segment facility sites (development phase): DEIMOS Puertollano, KIR-1 & CEB
- Equipment (development phase)



Manufacturing processes;

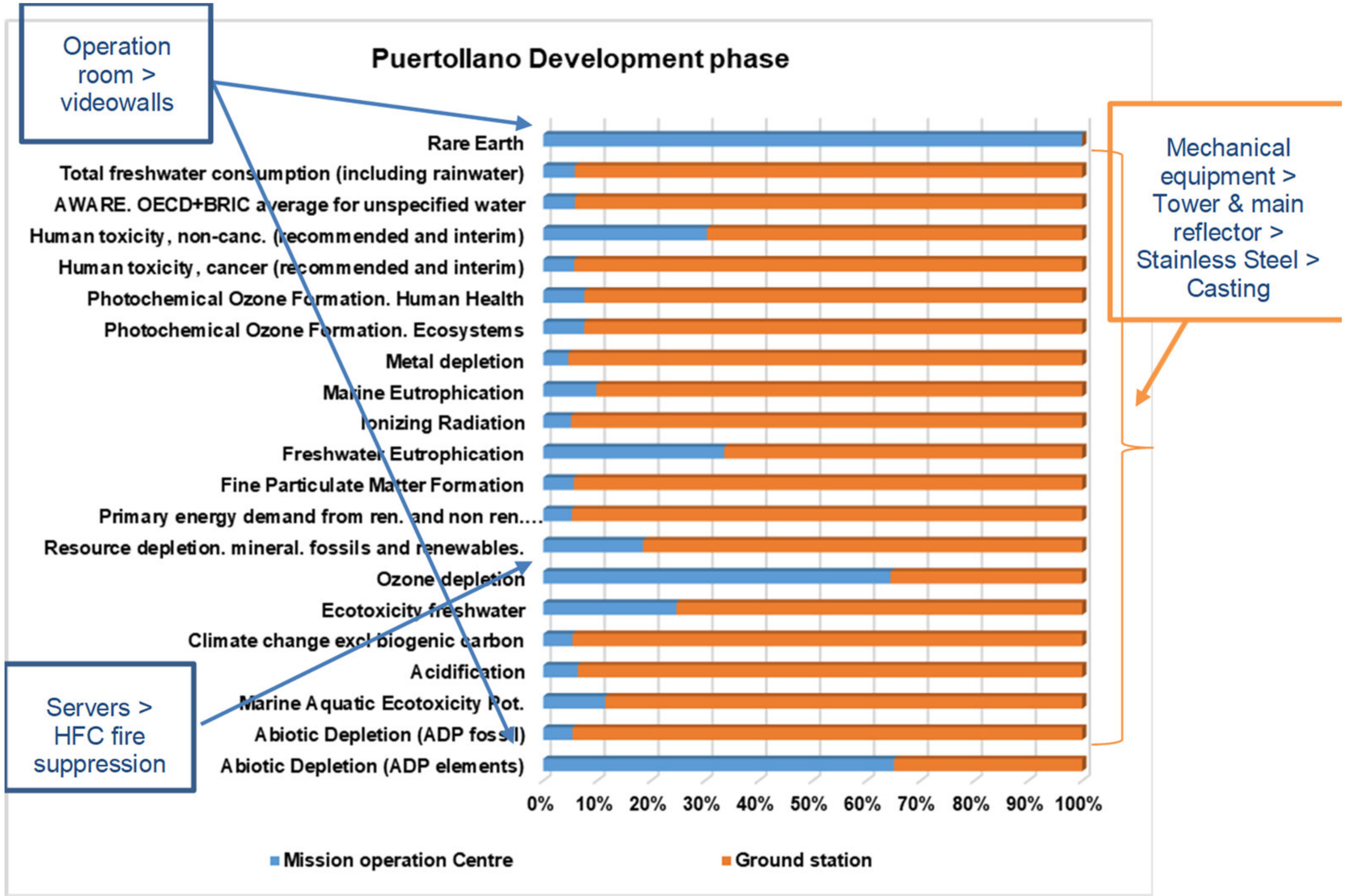
Raw materials.

Table 11.43: Azimuth motor model breakdown

Dataset Name		Azimuth motor		
Description		1 kg of Azimuth motor at the output gate		
Source		Deimos		
Relevance		All		
FU		1	kg	
Reference weight		29,5	kg	
Estimated energy consumption[30]		700	kWh - daily	
Name	**Breakdown**	**Quantity**	**Units**	**Life cycle inventory**
Material inputs				
Electronic unit – Low IC	2,5%	0,025	kg/FU	Electronic unit, low IC
Potentiometer	2,5%	0,025	kg/FU	GLO: potentiometer production, unspecified ecoinvent
Electric motor	40%	0,4	kg/FU	RER: electric motor production, ecoinvent
Casing - Stainless steel	35%	0,4	kg/FU	Stainless steel product
Copper	10%	0,1	kg/FU	GLO: market for copper ecoinvent 3.5
Other input				
Encoder	5%	0,05	kg/FU	Encoder
Manufacturing processes				
Metal working - copper	/	0,1	kg/FU	GLO: market for copper ecoinvent 3.5
Metal working - Steel	/	0,4	kg/FU	RER: metal working, average for steel product manufacturing

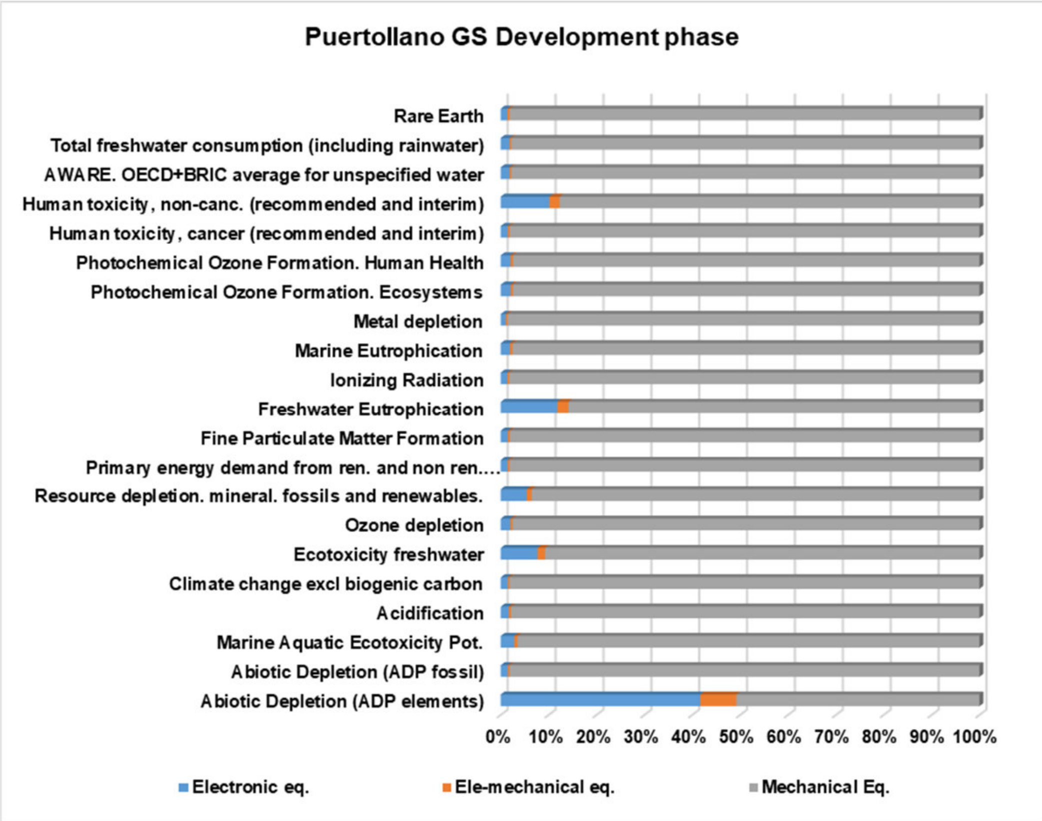
Task 2 & 3 – LCA of Ground Segment

Deimos Puertollano Ground Segment development phase impact assessment.



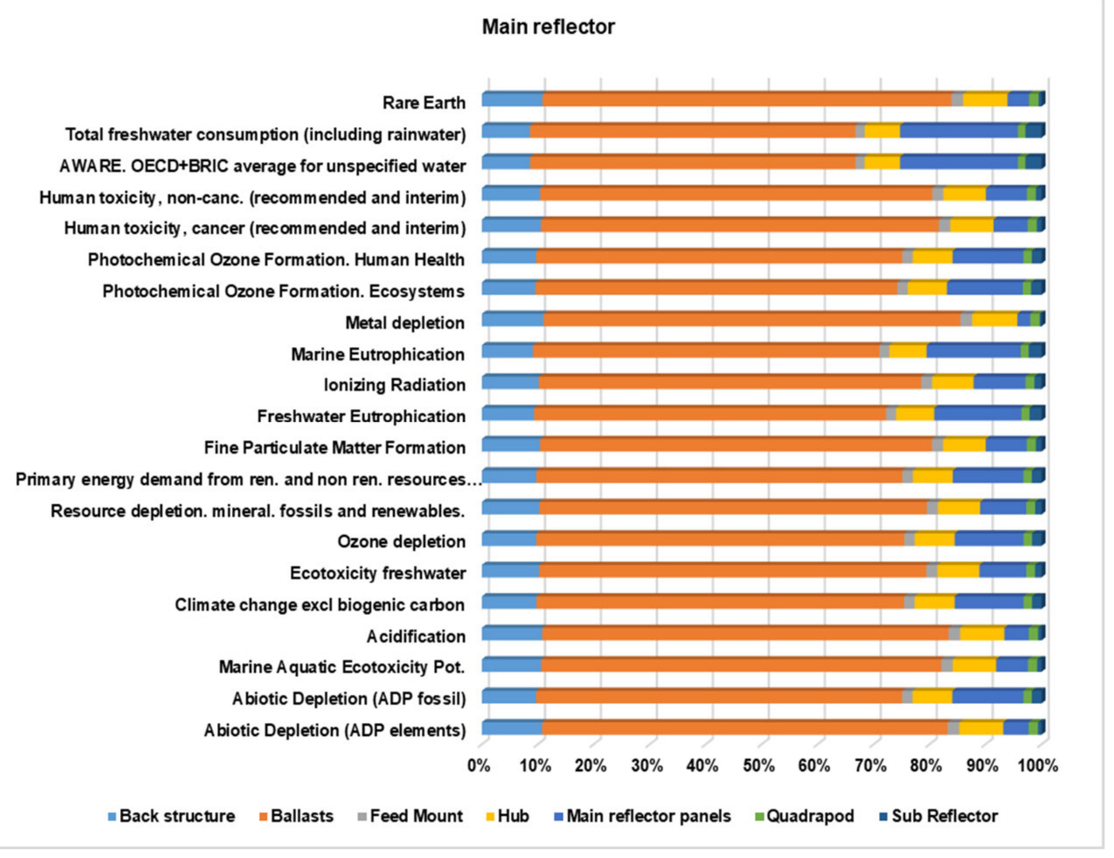
Task 2 & 3 – LCA of Ground Segment

Deimos Puertollano Ground Station development phase impact assessment.



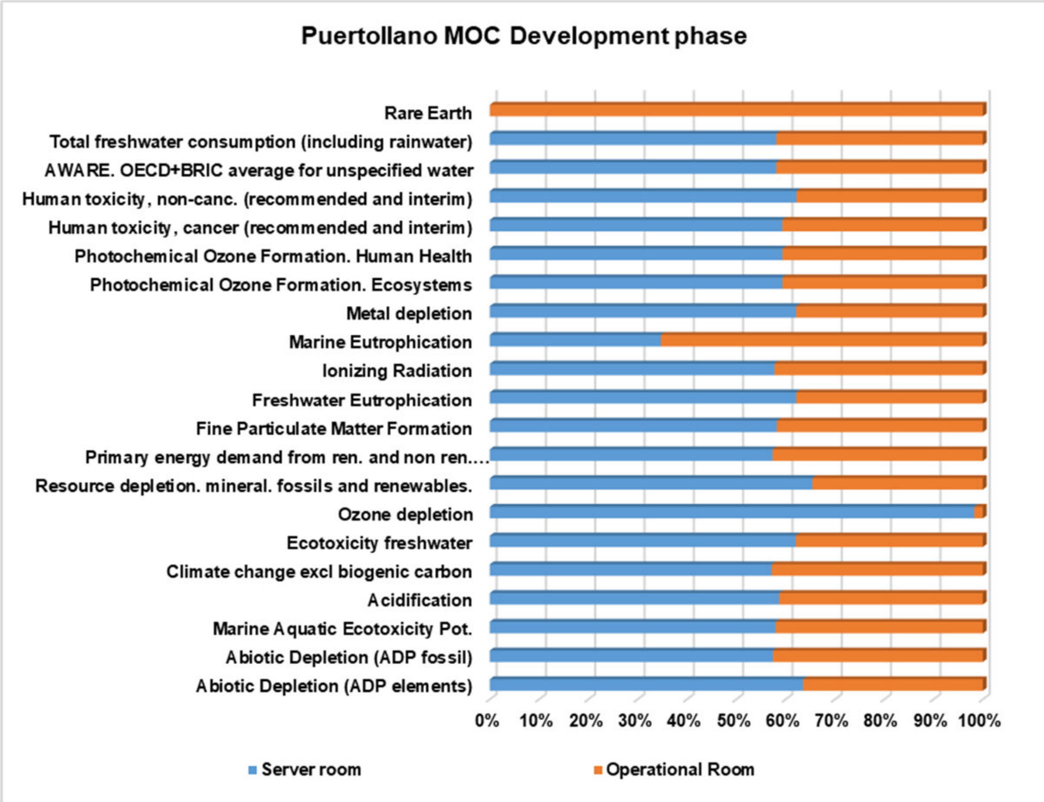
Task 2 & 3 – LCA of Ground Segment

Deimos Puertollano Main Reflector (main contributor) development phase impact contributions.



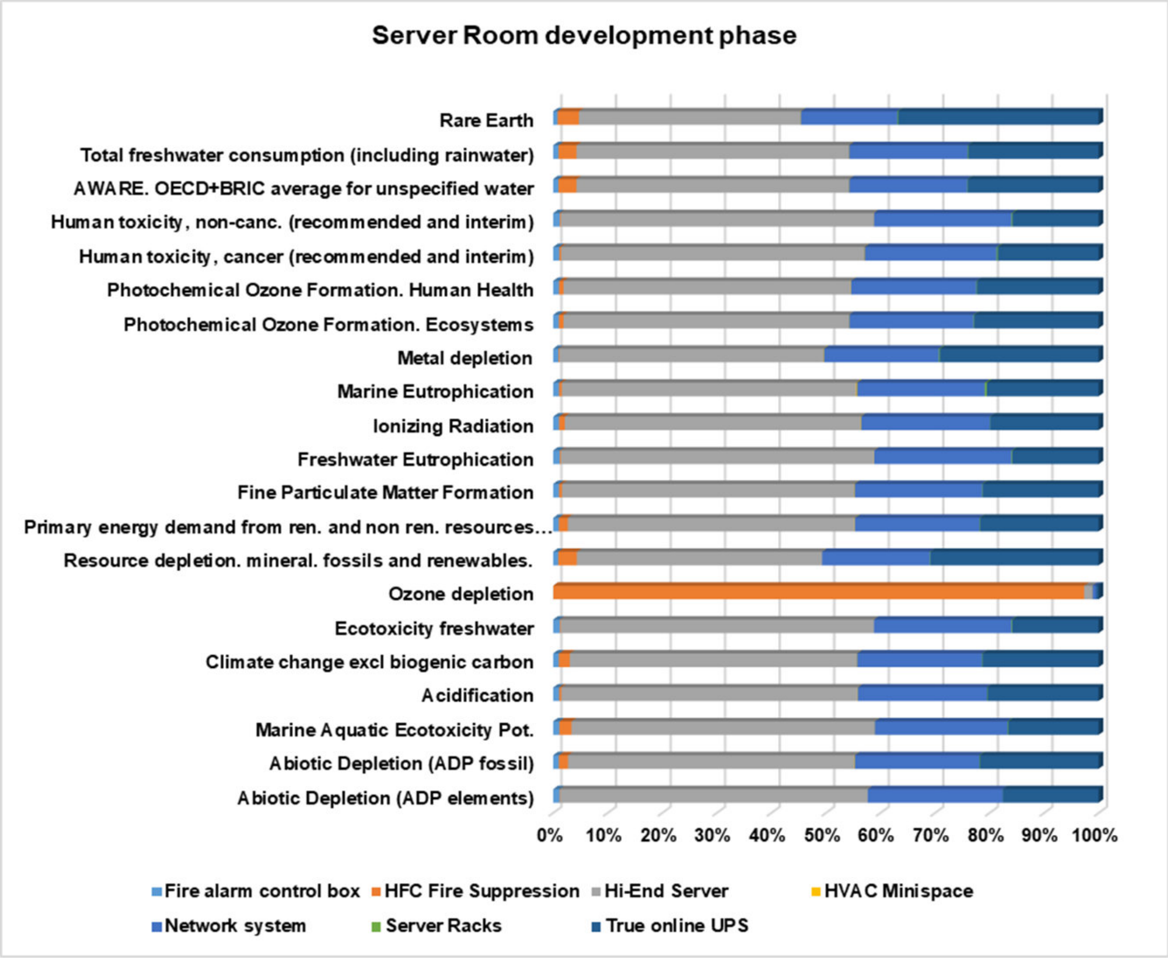
Task 2 & 3 – LCA of Ground Segment

Deimos Puertollano MOC development phase impacts.



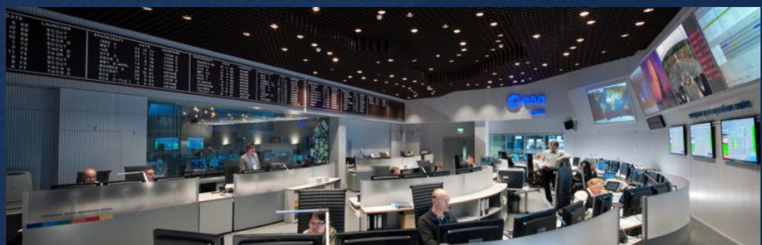
Task 2 & 3 – LCA of Ground Segment

Deimos Puertollano Server Room elements development phase impact contributions.



Task 2 & 3 - Life cycle impact assessment – Maintenance and operation (M&O)

- Ground segment facility sites (Maintenance and operation);



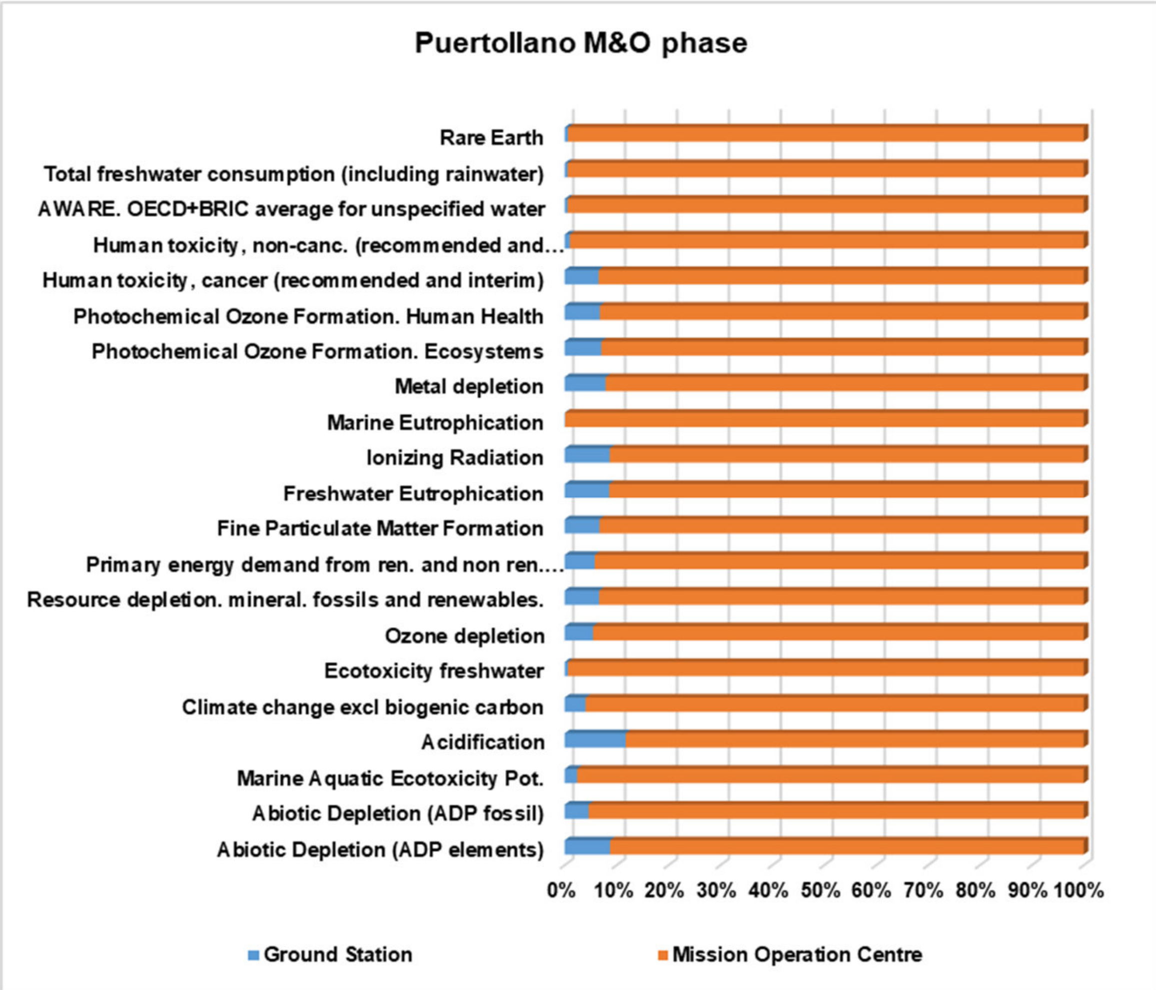
Consumptions

Table 10.8: Deimos Purtollano MOC M&O consumptions data

Dataset Name	Deimos Puertollano Mission Operation Centre (EO Mission – non ESA mission)		
Description	1 year of Mission Operation Centre M&O		
Source	Deimos		
Relevance	No ESA Space Missions - Earth Observation (Deimos-2)		
FU	1	Year of M&O of the facility considering its surface	
Facility surface	2796	m^2	
Name	**Quantity**	**Units**	**Life Cycle inventory**
Material inputs			
Electricity consumption	6720	kWh	Europe: market group for electricity, medium voltage
Water consumption	900000	kg	Europe without Switzerland: tap water production
Gas/Oil consumption	35060,4	MJ	Europe: Heat production, natural gas, at boiler atmospheric non-modulating <100kW
Diesel consumption	1018,7	kg	Europe: diesel production, low-sulfur
Paper consumption	500	kg	RER: paper production ecoinvent 3.5
Waste produced[11]			
Plastic waste	12954	kg	GLO: market for waste plastic, mixture, sanitary landfill ecoinvent
Paper waste	500	kg	GLO: treatment of waste graphical paper, unsanitary landfill, dry infiltration class (100mm) ecoinvent 3.5

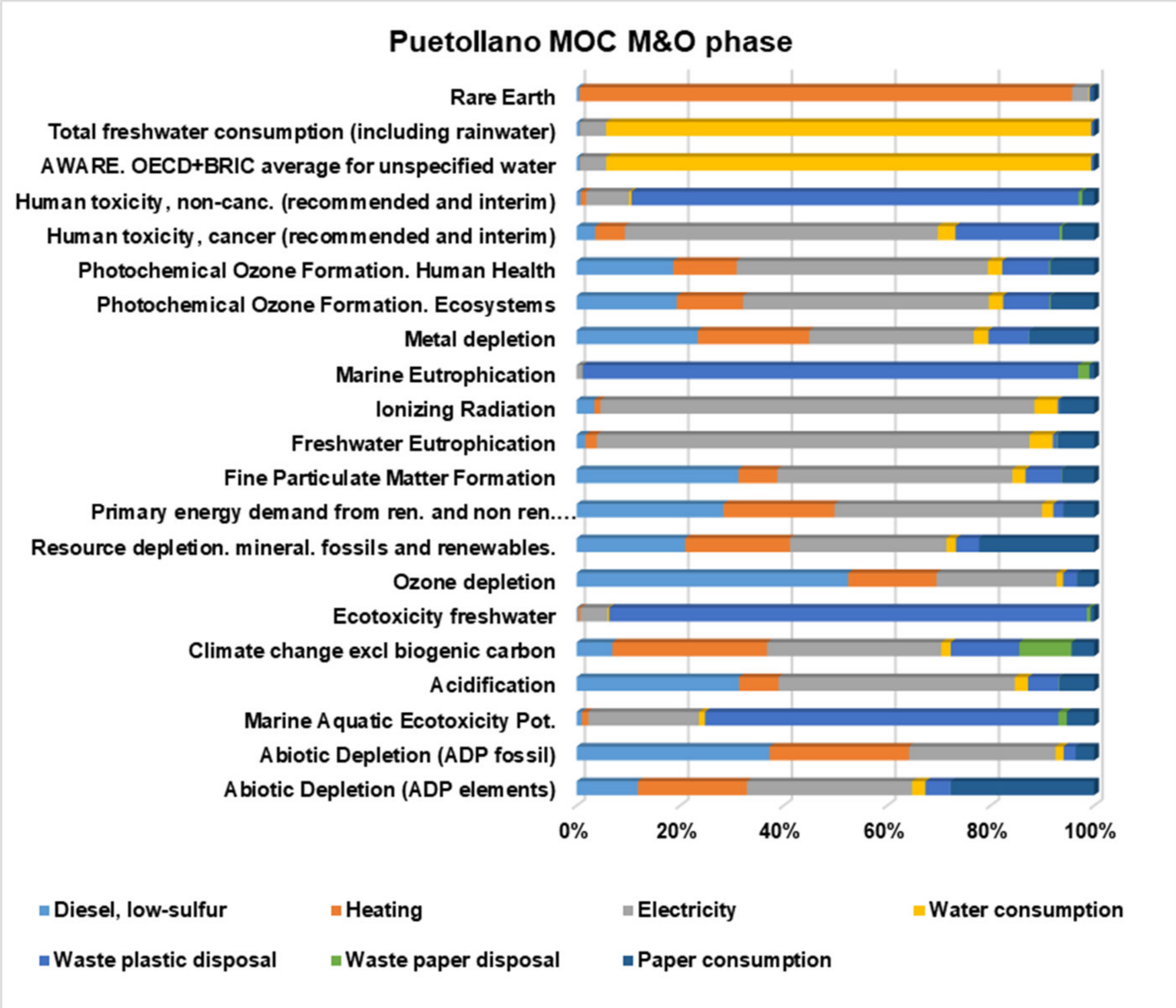
Task 3 – LCA of Ground Segment – 2°Iteration

Puertollano Ground Segment M&O phase impact assessment.



Task 3 – LCA of Ground Segment – 2° Iteration

Deimos Puertollano MOC M&O sources of impacts chart.



Task 2 & 3 - Life cycle impact assessment – mission: Deimos2 (Earth Observation)

Mission phases

"Deimos-2"	Phase A/B/C/D	Phase E1a - LEOP + Commissioning	Phase E2: utilization	Phase F (disposal)
Puertollano Ground Station (PL01) (hours)	0 hours	8.75 hours	3193.75 hours	37.5 hours
Kiruna Ground Station (hours) - assumed similar to PL01	0 hours	3.5 hours	638.75 hours	7.5 hours
Svalbard Ground station Station (hours) - assumed similar to PL01	0 hours	3.5 hours	638.75 hours	7.5 hours
Puertollano MOC (men-day)	1000 men-day	70 men-day	10556 men-day	60 men-day
Imaging processing center Puertollano (men-day) - assumed similar to Puertollano MOC		35 men-day	18564 men-day	0 men-day

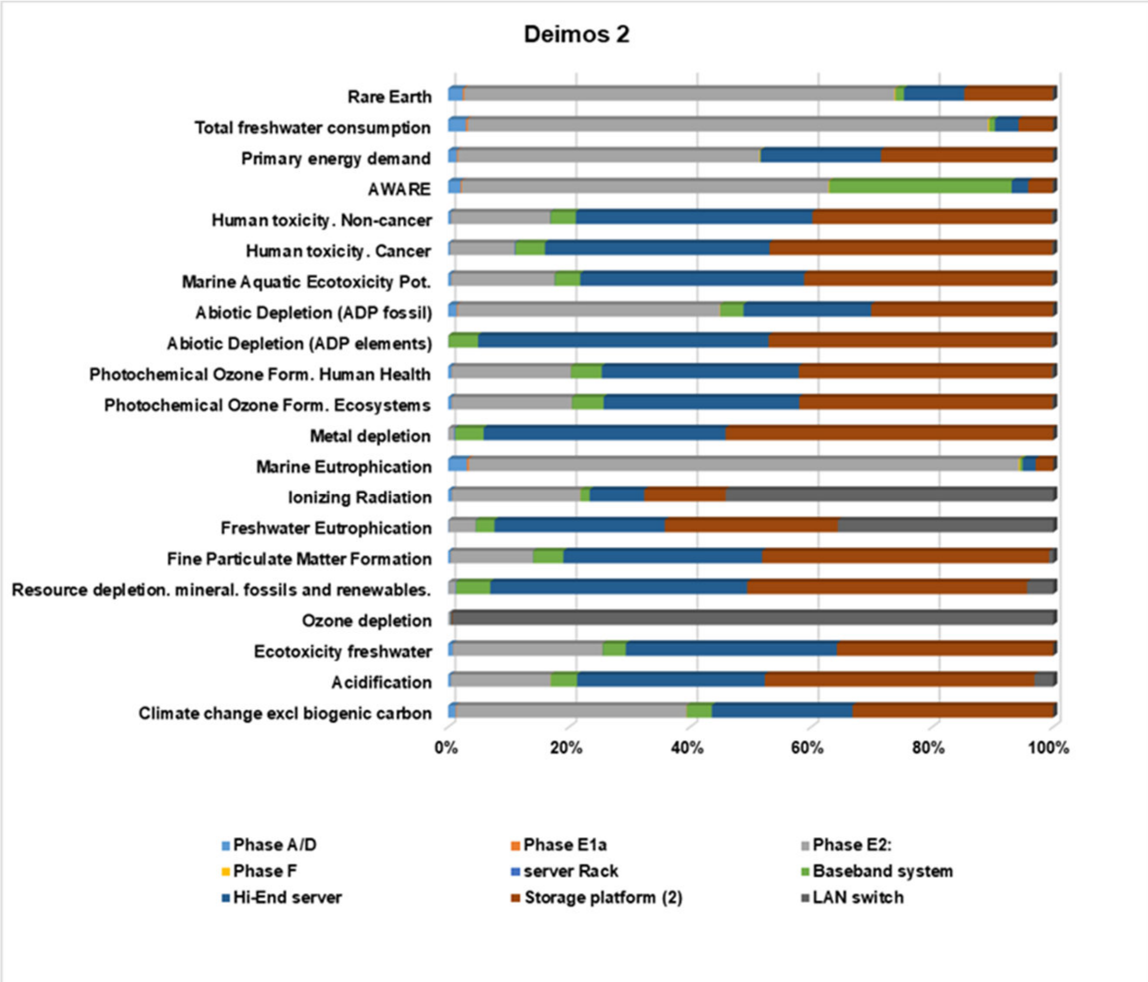
- Baseband system (mod/demodulator) x1 ;
- Hi-End x1;
- LAN switch x1;
- Server rack x1;
- Storage platform x2.

Mission facility efforts

Mission dedicated equipment.

Task 2 & 3 – LCA of Ground Segment

Deimos 2 EO mission LCIA

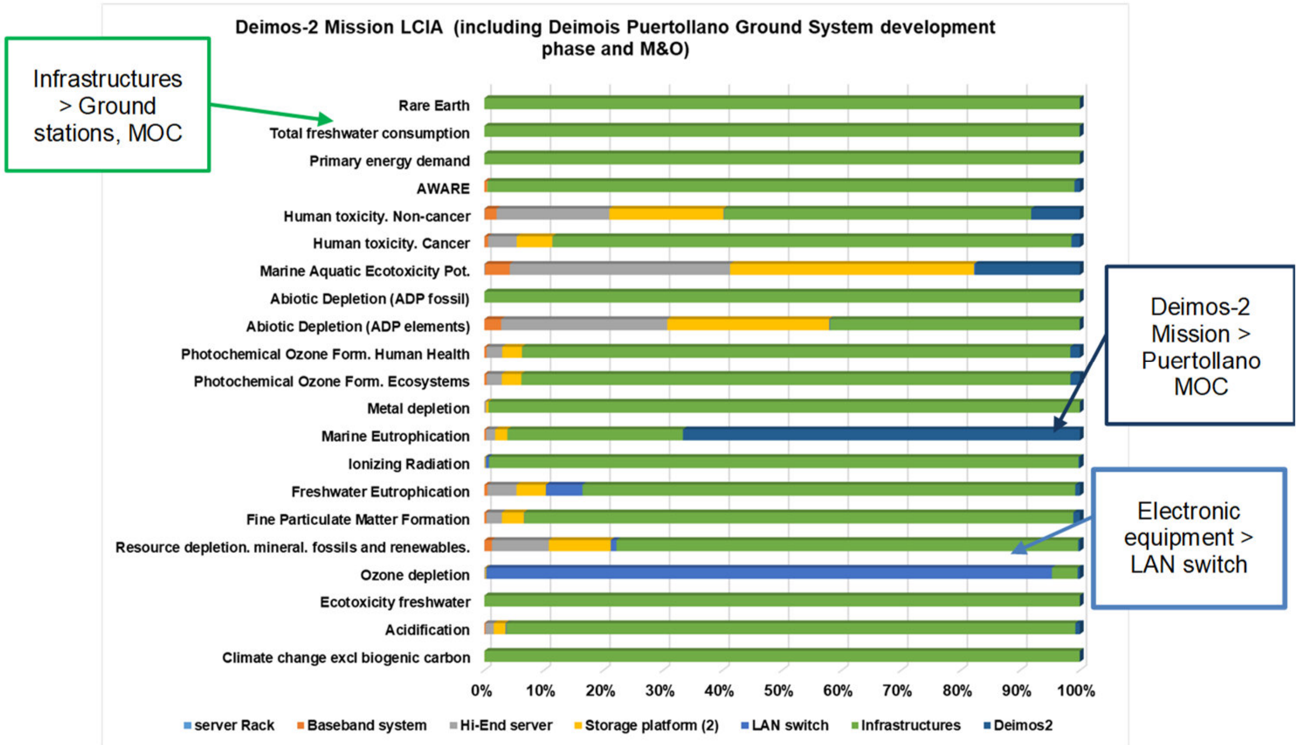


Task 2 & 3 – LCA of Ground Segment

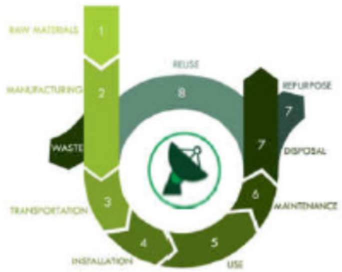
Integration between development phase and mission LCIA

Several data are needed: no. of missions managed by each facility and effort dedicated to each mission, the capacity of the facility (which can manage with the same assets more than the missions actually present), dedicated new equipment.

Only for Puertollano facilities this kind of information was available



Methodological Guidelines



ESA - ESTEC
Noordwijk, The Netherlands

Ground Segment LCA – Methodological and Quantitative

ESA Contract No. 4000123991/18/NL/GLC/as TN1 – Methodological framework for Ground Segment LCA

Doc. No. P0008945-1-H4 Rev. 3 – January 2020

Rev.	3
Description	Fourth issue
Prepared by	M. De Santis (RINA)
Controlled by	G. Urbano (RINA)
Approved by	S. Morales (ESA)
Date	January 2020

Task 4 - Ecodesign activities

ESA - ESTEC
Noordwijk, The Netherlands

Ground Segment LCA – Methodological and Quantitative

ESA Contract No. 4000123991/18/NL/GLC/as TN4 – Results analysis and eco-design

Doc. No. P0008945-1-H6 Rev. 0

Rev.	0
Description	First Issue
Prepared by	S. Rommelaere (CT), M. De Santis, S. D'Errico (RINA)
Controlled by	G. Urbano (RINA)
Approved by	S. Morales (ESA)
Date	February 2020

Task 4 – Workflow of activities

LCA results

T4.1
- Analysis of environmental impacts
  → Hotspots identification

T4.2
- Brainstorming for eco-design options
  → Options selection

T4.3
- Eco-design options developed into solutions
  → solutions preliminary design, maturity, performances

T4.4
- LCA analysis of the solutions
  → environmental savings

T4.5
- Steps for development
  → Roadmap for solutions implementation

Task 4 – LCA results analysis - Conclusion

Comparison facility development vs facility operation

		Climate Change	Metal depletion	Human toxicity, cancer	
Puertollano (MOC+GT)	**M&O phase** (impact of 1 year)	$9{,}1x10^{3}$	6,5	$4{,}7x10^{-4}$	
	Development Phase (total impact)	**$3{,}3 \ x10^{6}$**	**$1{,}7 \ x10^{5}$**	**$8{,}2 \ x10^{-1}$**	*Mainly governed by stainless steel (+ PWB)*
ESOC MOC	**M&O phase** (impact of 1 year)	**$6{,}8 \ x10^{6}$**	$4{,}27 \ x10^{3}$	**$5{,}36 \ x10^{-1}$**	*Mainly governed by electricity consumption*

Very high impact:

- **Electricity consumption** in O&M phase
- **Stainless steel manufacturing** in Development phase in GT mechanical equipment

Medium impact:

- **Printed Wiring Board** in Development phase in MOC/SOC electronic equipment

Task 4 – Eco-design options selection

Main hotsposts

Functional

- Hotspots breakdown
- Criteria and weights

Creativity

- Brainstorming
- Creativity techniques (ideas purge, analogy, mind maps, etc.)

Valuation

- Assessment of ideas
  → Multi-criteria analysis

3 eco-design options

Work performed during work meetings with RINA, DEIMOS, CT and ESA

Task 4 – Eco-design options selection

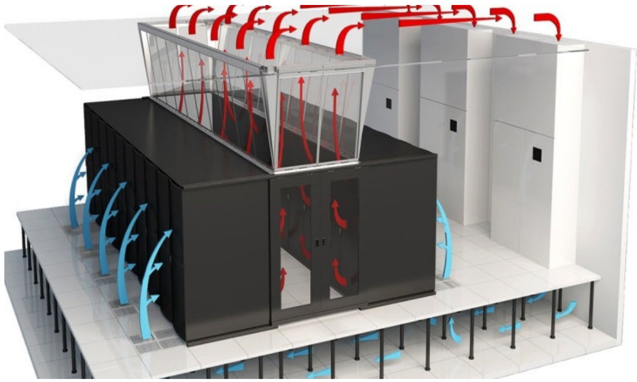
Hotspot	Environment: Hotspot environmental contribution (20%)	ID	Eco-design solution	Environment: Environmental savings (10%)	Cost: Development and implementation cost (10%)	Cost: Recurring cost (15%)	Technology: Innovation (10%)	Technology: Maturity (10%)	Technology: Scalability (15%)	Technology: Implementation impact (10%)	TOTAL	LCA feasibility
Electricity consumption in the facilities' daily operation	5,0	S1	Replace video walls & work stations with new, low energy consumption hardware	1,0	5,0	5,0	1,0	5,0	3,0	5,0	3,90	No
		S2	Install hot aisle containment and adiabatic or free cooling in server rooms	3,0	4,0	5,0	3,0	5,0	4,0	5,0	4,35	Yes
		S3	Implement virtualization for hi end servers and storage platform	3,0	4,0	5,0	1,0	5,0	4,0	4,0	4,05	No
		S4	Implement an energy management system to optimize production, storage and consumption	2,0	3,0	4,0	3,0	5,0	2,0	3,0	3,50	No
		S5	Implement real-time monitoring with connected sensors (IoT)	2,0	5,0	4,0	2,0	5,0	5,0	5,0	4,25	Yes
Stainless steel use in equipment manufacturing	5,0	S6	Re-use existing antenna	4,7	4,7	4,3	1,0	[illegible]	4,3	4,0	4,23	Yes
		S7	Create a catalog of towers of different sizes --> discarded								0,00	Yes
		S8	Optimize reflector manufacturing to reduce reflector's size and antenna's mass	3,3	3,3	5,[illegible]	1,[illegible]	4,3	4,7	4,3	4,12	Yes
		S9	Different design solutions for overall lighter design	4,0	3,0	[illegible]	1,0	5,0	5,0	5,0	4,30	Yes
		S10	Recycle stainless steel at GT end-of-life	1,7	[illegible]	3,7	1,0	5,0	4,3	5,0	3,83	Yes
		S11	Increase the use of recycled stainless steel	2,0	4,0	3,7	1,3	4,3	4,0	4,7	3,78	Yes
		S12	Use alternative material (reinforced concrete) for the GT tower and ballasts	5,0	5,0	4,0	2,0	2,0	5,0	5,0	4,25	Yes
		S13	Use of aluminum for GT non-structural parts	1,3	4,7	3,7	1,0	3,0	4,0	4,3	3,58	Yes
PWBs manufacturing for the IC units	3,0	S14	State in requirements for the electronic equipment providers	3,0	2,5	3,0	3,0	4,0	4,5	4,5	3,43	No
		S15	Implement preventive maintenance operations (using sensors measurements)	1,0	4,0	3,0	1,5	5,0	4,0	2,5	3,05	No
		S16	Implement redundancy of critical components	1,5	3,0	2,5	3,0	3,0	3,5	4,5	3,00	No
		S17	Maintain environmental conditions during operations	1,5	3,0	2,0	2,5	4,5	3,5	3,0	2,88	No
		S18	Use electronics with 3D-printed PWB	1,3	2,0	3,0	3,0	3,0	2,0	4,3	2,72	Yes

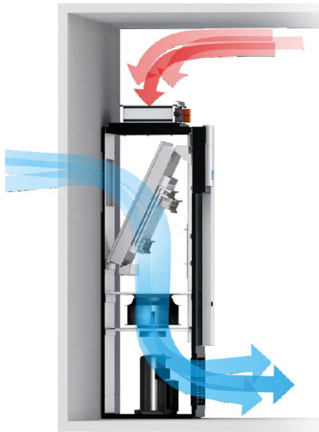
Task 4 – Solutions

Hotspot	ID	Eco-design solution	TOTAL
Electricity consumption in the facilities' daily operation	S1	Replace video walls & work stations with new, low energy consumption hardware	3,90
	S2	Install hot aisle containment and adiabatic or free cooling in server rooms	4,35
	S3	Implement virtualization for hi end servers and storage platform	4,05
	S4	Implement an energy management system to optimize production, storage and consumption	3,50
	S5	Implement real-time monitoring with connected sensors (IoT)	4,25

Stainless steel use in equipment manufacturing	S6	Re-use existing antenna	4,23
	S7	Create a catalog of towers of different sizes --> discarded	0,00
	S8	Optimize reflector manufacturing to reduce reflector's size and antenna's mass	4,12
	S9	Different design solutions for overall lighter design	4,30
	S10	Recycle stainless steel at GT end-of-life	3,83
	S11	Increase the use of recycled stainless steel	3,78
	S12	Use alternative material (reinforced concrete) for the GT tower and ballasts	4,25
	S13	Use of aluminum for GT non-structural parts	3,58
PWBs manufacturing for the IC units	S14	State in requirements for the electronic equipment providers	3,43
	S15	Implement preventive maintenance operations (using sensors measurements)	3,05
	S16	Implement redundancy of critical components	3,00
	S17	Maintain environmental conditions during operations	2,88
	S18	Use electronics with 3D-printed PWB	2,72

Task 4 – Solution: Install Hot Aisle Containment and adiabatic or free cooling in server rooms





Hot Aisle Containment:

- Requires row layout and ceiling ducts
- Up to 46% cooling energy reduction

LCA results: **38% savings** on climate change impact

Free cooling:

- Requires access to outside
- Up to 90% cooling energy reduction

Both solutions are commercially available, but prices not communicated.

Timeframe for implementation: few months to a year,

Applicable on **existing server rooms.**

Task 4 – Solution: Different design solutions for overall lighter design

Reduce the antenna mass, example:

PL-01: 10,2m/55tons vs PL-03: 11m/18tons

Price also divided by 2

LCA results: ~**60% savings** on 3 cat.

Network of smaller antennas:

10m/55tons vs 3,7m/2tons

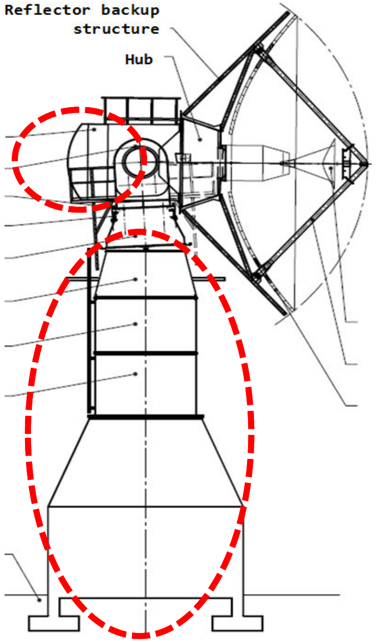
Performances different → Follow market trend

LCA results: ~**11% savings** on 3 cat.

Both solutions: technically and commercially feasible

Implementation: only applies **to future antennas/networks**, must be driven by market evolution, continuous improvement

Task 4 – Solution: use alternative material for the GT tower and ballasts



Use of concrete

- Stainless steel tower → **reinforced concrete:** matches structural requirements
  ~33% savings
- Stainless steel ballast → **concrete into a stainless steel shell:** mass
  ~36% savings

High maturity, produced locally, recycled/recyclable

More complex civil work

Implementation: a year, study (small antenna? location?)

Cost: +40k€ for tower like PL-01

Conclusions

Some final recommendations for future deeper LCA application for GS:

- Require further detailed inputs to confirm preliminary conclusions from this activity at ground segment type level, mainly related to **Ground system development phase**

- Recommendation to **assess electrical consumption reduction measures** at ground segment level, for data centers by e.g. combining/sharing resources, due to the huge amount of electricity required by them

- Recommendation to increase Research and Technological funding in development of **local independent and sustainable electrical production means**, like green sources (i.e. photovoltaic, wind) with use of **batteries for the management of peaks**

Thanks for the attention!

Michele De Santis
michele.desantis@rina.org