2023 ESA Clean Space Industry Days

Overview of Life Cycle Assessment and EcoDesign Activities for Large Space Missions at Thales Alenia Space

M. Giuliani

Date : 17-Oct--23
Ref : 0005-0014398974
Rif. Modulo : 83230347-DOC-TAS-IT-008

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Thales Alenia Space Involvement in LCA Projects

Thales Alenia Space is involved in LCA activities for several Large Missions both as Prime Contractor and as Sub-Contractor, implying different development stages (Phases A/B1, B2, C)

Thales Alenia Space as Prime Contractor	
ROSE-L - Satellites	DON-I *(TAS-I Rome)*
CIMR - Satellites	DON-I *(TAS-I Rome)*
CHIME - Satellite	DOS-F *(TAS-F Cannes)*
S1NG - Satellite	DON-I *(TAS-I Rome)*
G2SB1-A Satellites	DON-I *(TAS-I Rome)*
Other Projects with several commercial operators – *on-going*	DOS-F *(TAS-F Cannes)*

Thales Alenia Space as Sub-Contractor	
CO2M - 3 Payload Instruments	DOS-F *(TAS-F Cannes)*
CRISTAL - IRIS Instrument	DOS-F *(TAS-F Cannes)*

- *DON-I = Domain "Observation / Navigation" - Italy*
- *DOS-F = Domain "Observation / Science" - France*

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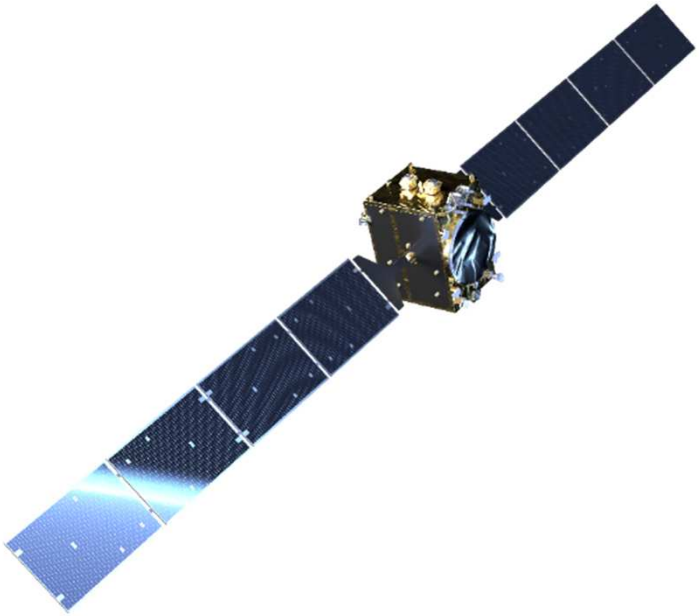
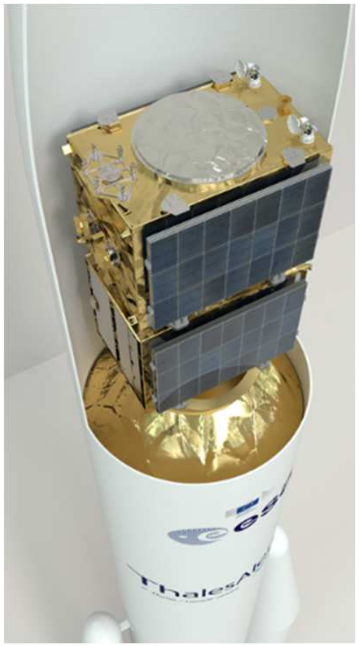
Thales Alenia Space Involvement in LCA Projects



G2SB1-A
Deployed configuration



G2SB1-A
Dual launch stacked configuration

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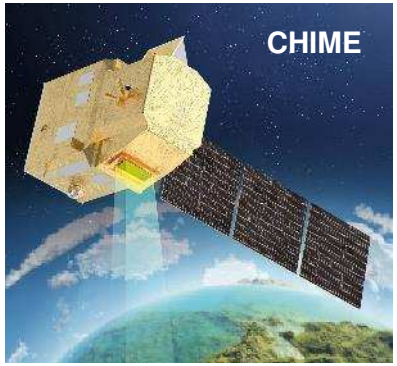
Thales Alenia Space Involvement in LCA Projects



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LCA Activities / Driving Requirements

As Prime Contractor

Explicit Requirements in ESA SoW for:

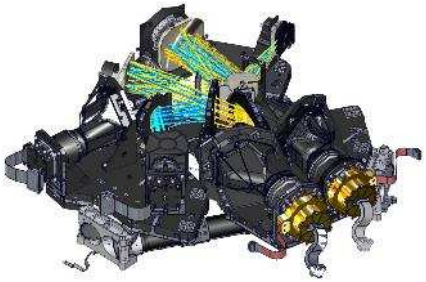
- LCA Iterations
  - Up to 3 (as a minimum) at S-PDR, S-CDR, (S-QAR)
  - All Mission Phases A/B/C/D/E1a are included, except:
    - Launch campaign activities applicable to the launcher segment only or to the combined operations
    - Launch
- LCA Data Quality Rating
  - ≤ 3 for each Data Quality Indicators [TeR], [GR], [TiR], [C], [P], [M] @S-CDR
- Tailoring of ESSB-HB-U-005 “Space system Life Cycle Assessment (LCA) guidelines” for the relevant phases
  - LCI data:
    - Characterization of availability and maturity
    - Identification of sources and collection method
  - Analysis of “ESA LCA Guidelines” applicability to relevant phases
  - Tailoring of potentially most time consuming guidelines (DQR, Cut-Off), to allow their optimized implementation, effort-wise, tailoring of LCA methodology

Thales Alenia Space Involvement in LCA Projects

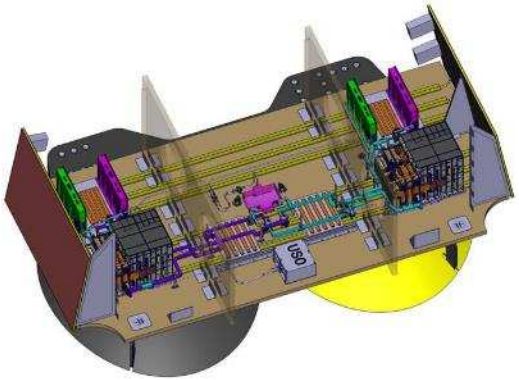
As Sub-Contractor

Provision of LCI Data
(as per Prime Contractor LCI Data Collection questionnaire)

CO2M Payload
(including CO2i/MAP & CLIM)



CO2i spectrometer



CRISTAL Payload (IRIS)

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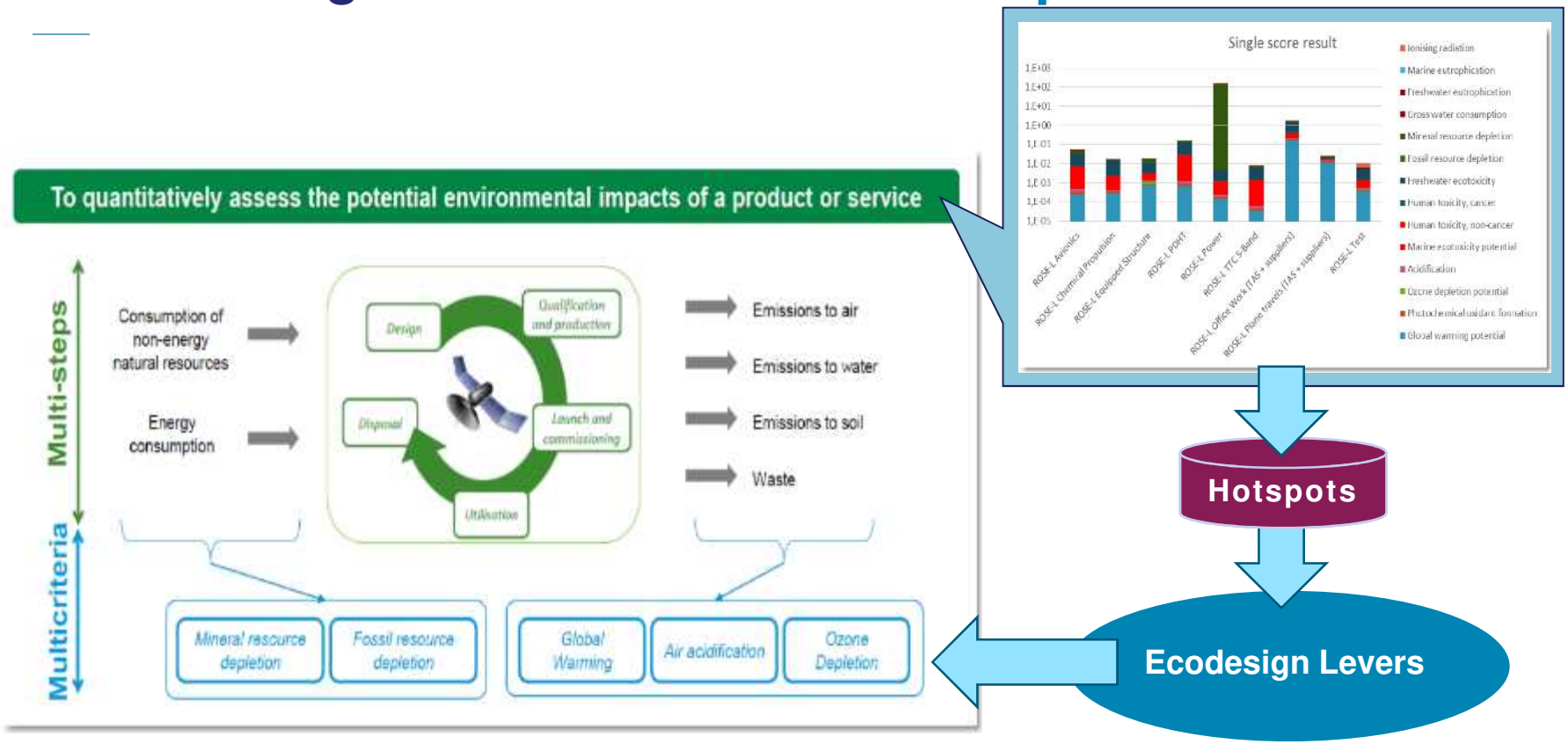
Introducing LCA – Definition and Purpose



Life Cycle Assessment / Introduction & Approach

❶ MULTI-STEPS

All stages of the life cycle are taken into account

❸ SYSTEMIC

Everything related to the product is taken into account: the product, packaging, associated and ancillary products, etc.

❷ MULTI-INDICATORS

All significant environmental impacts generated by the product are measured

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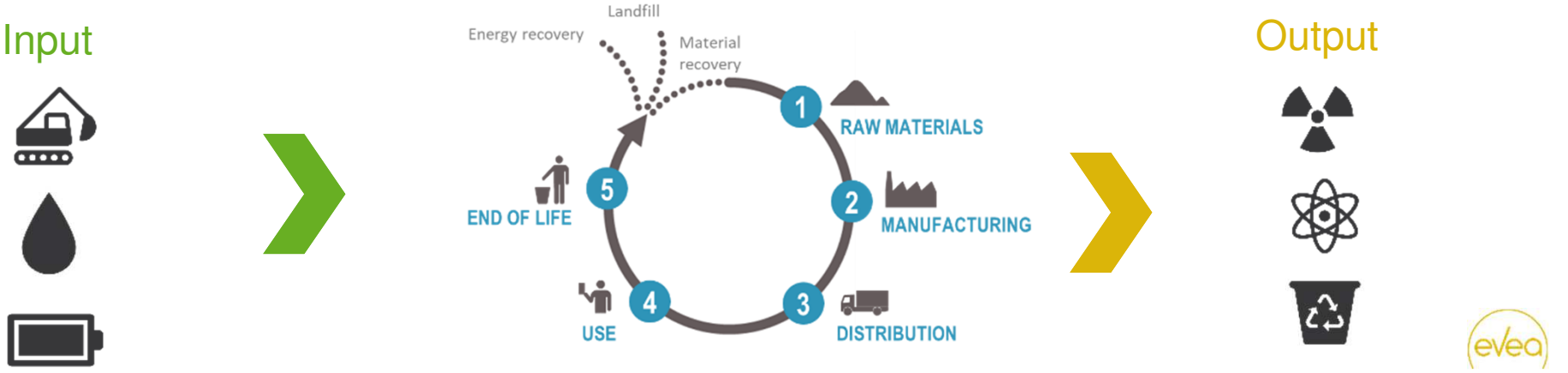
Life Cycle Assessment / Introduction & Approach

❶ MULTI-STEPS

The "product" approach takes into account all stages of the life cycle

Definition of life cycle (ISO 14040:2006)

"Consecutive and linked phases of a product system, from the acquisition of raw materials or the generation of natural resources to the final disposal"



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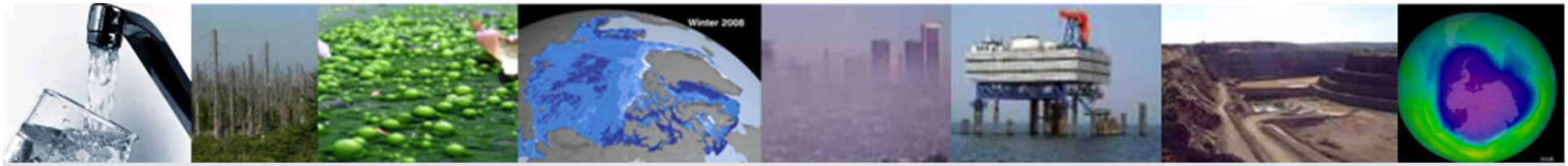
Life Cycle Assessment / Introduction & Approach

❷ MULTI-INDICATORS

Consideration of all significant environmental impacts generated by the product

On all 16 indicators of the Environmental Footprint 3.0 methodology (European Commission)

- Climate change
- Ozone depletion
- Ionising radiation
- Photochemical ozone formation
- Particulate matter
- Human toxicity, non-cancer
- Human toxicity, cancer
- Acidification
- Eutrophication, freshwater
- Eutrophication, marine
- Eutrophication, terrestrial
- Ecotoxicity, freshwater
- Land use
- Water use
- Resource use, fossils
- Resource use, minerals and metals



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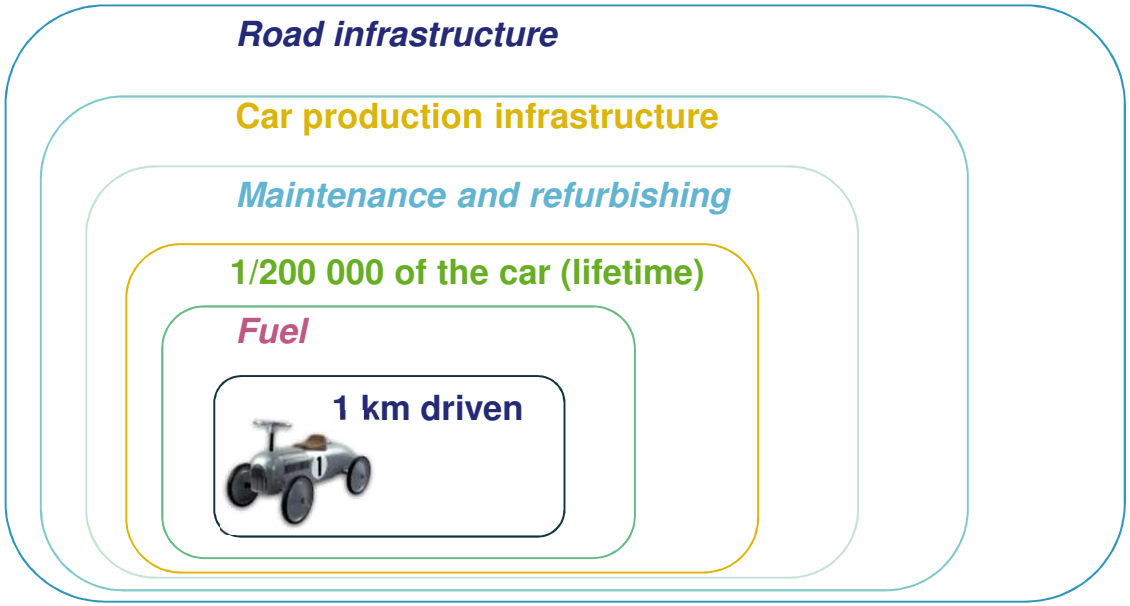
Life Cycle Assessment / Introduction & Approach

❸ SYSTEMIC

Take into account all systems in the FU: the product, packaging, associated products, etc.



FU*: To fulfil the requirements of the Space Segment Element Design Specifications in the frame of the Mission*

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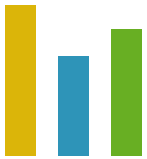
Life Cycle Assessment / Introduction & Approach

MULTI-STEPS

MULTI-INDICATORS



SYSTEMIC

AVOIDING BURDEN SHIFTING

When implementing Eco-Design levers

From one phase of the life cycle to another, but also from one indicator to another

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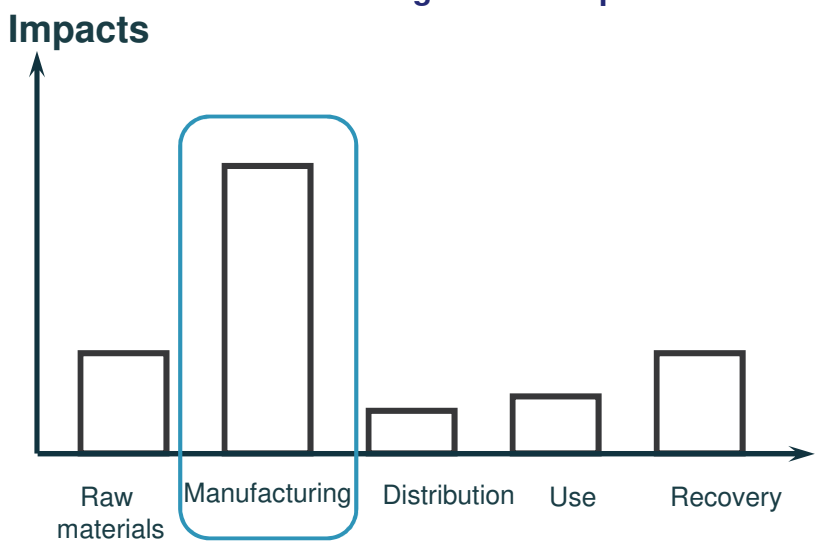
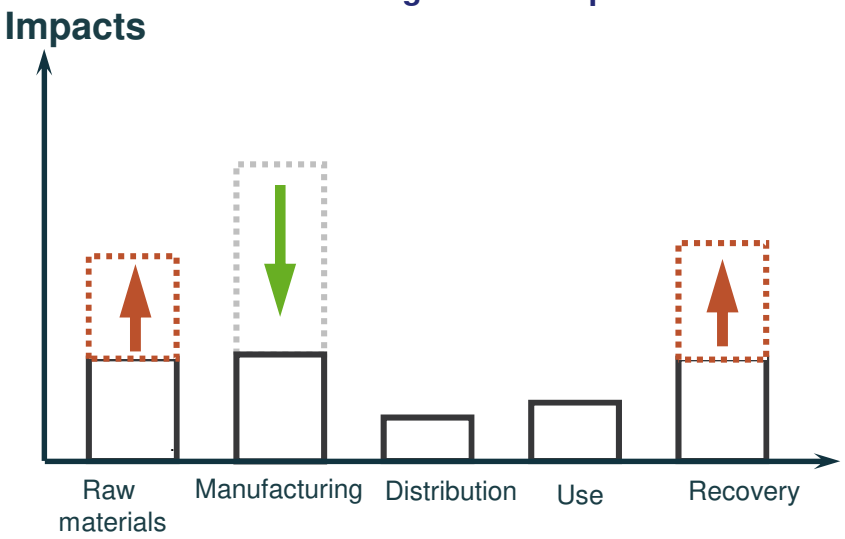
Life Cycle Assessment / Introduction & Approach

Before Ecodesign levers implementation



After Ecodesign levers implementation



Source : ADEME

1. The major environmental impact is generated during manufacture

2. Reduction of impact during manufacturing but increasing w.r.t. other stages

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Life Cycle Assessment / Methodology

SimaPro : worldwide LCA software

Goal and scope definition

Modeling
And calculation of environmental impacts by means of SimaPro software

Communication

1 → 2 → 3 → 4 → 5

LCI Data collection
(= flow inventory)

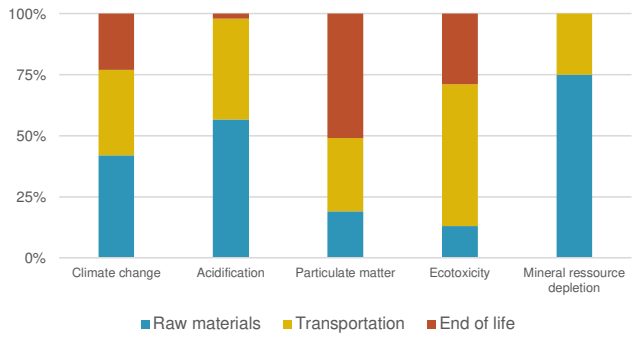
Product BOM:
- Components
- Materials, process, finishes
- Mass

Packaging BOM
(primary, secondary and tertiary) :
- Components
- Materials, process, finishes
- Mass

Manufacturing processes and conditioning:
- Energy or (device's power * duration)
- Country
- Consumables & spare parts

Transports:
- Mode of transportation (Truck, boat, plane)
- Distance
- Occupancy rate

Interpretation



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LCA / Goal & Scope, Intended Application(s)

- Space Segment "***from cradle to gate***" LCA (up to E1a Phase) for integration in a System LCA;
- Enhance the ESA LCA database for the LCA of future missions, thanks to the creation of **new LCI datasets**
- Assessment of the environmental impact of the Functional Unit (FU) under study, and identification of the related sources;
- Identification of the **hotspots** in the life cycle of the Mission, in order to find out which materials, components and processes have the highest contribution to the environmental impact of the whole satellite
- Identification of **eco-design levers**

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LCA / Functional Unit (FU)

- **FU:**

"*To fulfil the requirements of the Space Segment Element Design Specifications in the frame of the Mission*"

- **Reference Flow:**
  - FU includes PFM and FMs
  - The PFM includes the lower-level development models at Satellite level and Equipment (BB, SM, STM, EM, QM…)
    - Precisely modeled whenever possible
    - In early phases , modeled as a percentage of PFM environmental contribution (in terms of resources and energy consumption and manhours)

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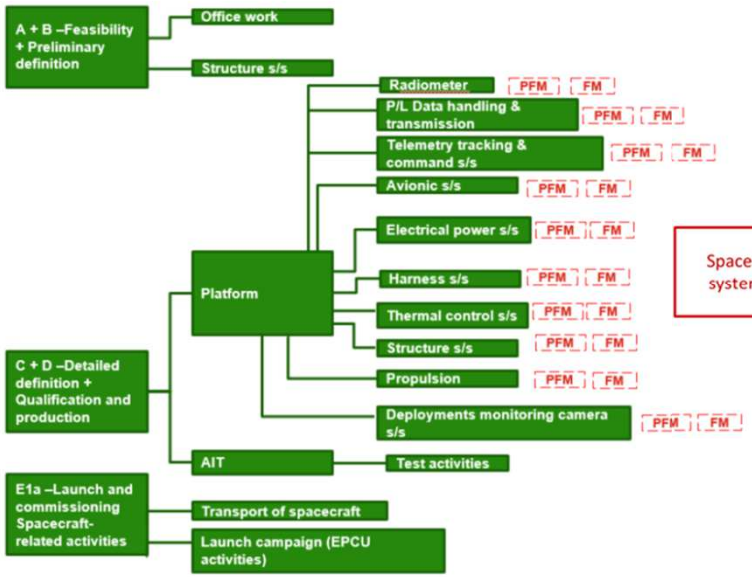
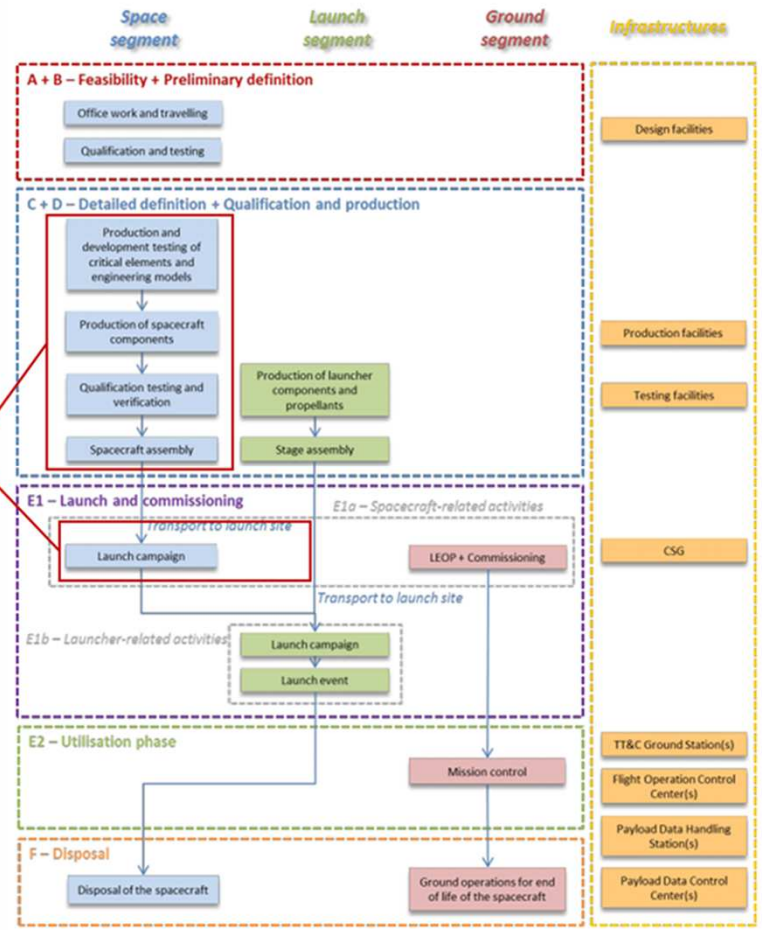
LCA / System Boundaries



Space segment LCA system boundaries



Typically Phases B2+C+D+E1a

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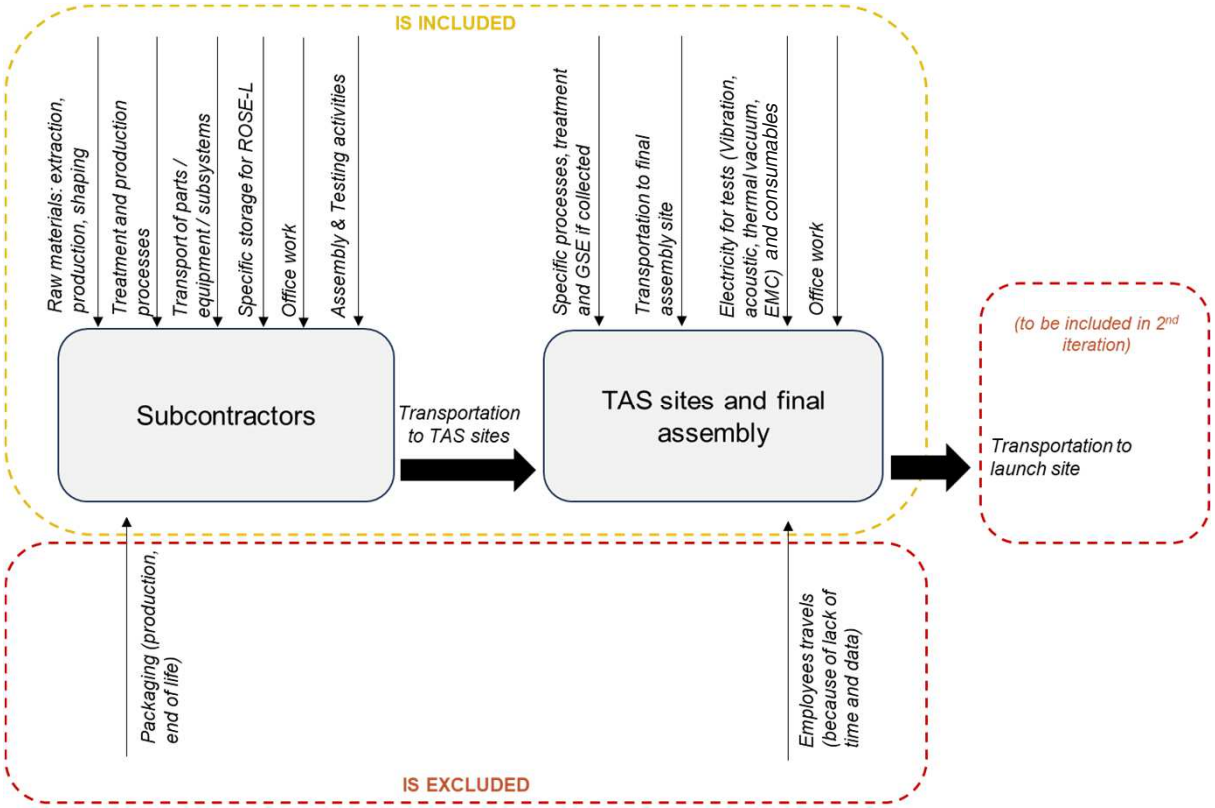
LCA / System Boundaries



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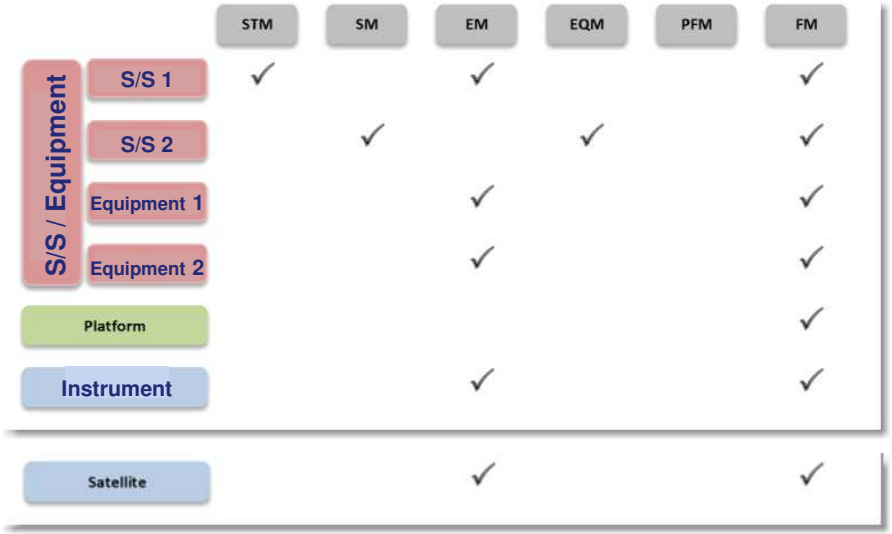
LCA / Life Cycle Inventory – LCI Data Collection

Activities
Production / Assembly / Storage
Satellite Elements Production
GSE Production
Satellite Assembly
Satellite Storage
Bake-out / Testing
Elements Bake-out
Elements and Satellite Testing
Office Work / Travels
Office Work
Travels
New Infrastructures (mandatory for program execution)
New Infrastructures Construction and Dismantling
New Infrastructures Equipment Manufacturing and Disposal
Launch Campaign
Satellite Integration



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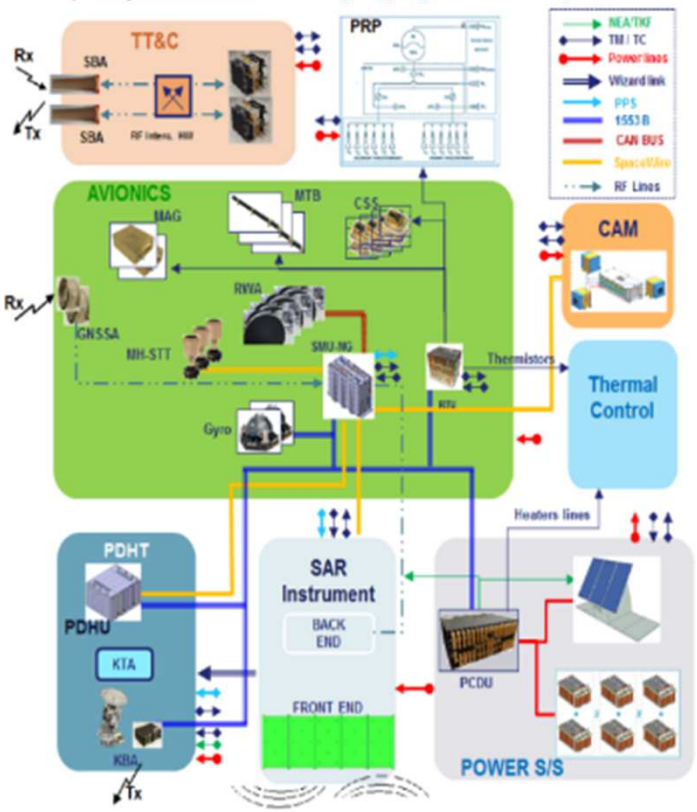
LCA / Main (typical) assemblies considered



SYNTHETIC APERTURE RADAR PL: • Instrument Front-End • Instrument Back-End	**CAMERA** • Monitoring Camera • Camera electronics	**P/L DATA HANDLING & TRANSMISSION** • Payload data and handling unit • K-band transmission assembly • Ka-band antenna assembly
TELEMETRY TRACKING & COMMAND S/S • S-band transponder • S-band antenna & RF miscellanea	**AVIONIC S/S** • On board computer • RTU • Gyroscope • Reaction wheel • Corse sun sensor • Magnetotorquer • Magnetometer • Star tracker • GNSS antenna	**ELECTRICAL POWER S/S** • Power conditioning & distribution unit • Battery assembly • Solar array wing
HARNESS SC • Bus dc harness • 1553 data bus • Wizard link cables • PDHT DC harness • Spacewire cables assy • Bus RF harness	**THERMAL CONTROL S/S**	**STRUCTURE S/S**
PROPULSION S/S		

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LCA / LCI Data Collection – Tools: LCI Data Sources

Data Type For all model types (i.e. EM, STM, QM, PFM, FM…) manufactured in the frame of the Program, including dummies.	Data Status …				Data Source Straight text: Generic data *Italk text: Instantiated data*				Source Owner Straight text: Generic data *Italk text: Instantiated data*		Data Collection Method	Comments / *Remarks*
	… for "Copernicus Mission" Program…				Type	*Title*	*Reference*	*Date*	Role	*Name*		
	… PDR preparation		… CDR preparation									
	Availability / Existence	Maturity	Availability / Existence	Maturity								
Bake-out / Testing												
Elements Bake-out												
Bake-out												
Bake-out Facility Energy Consumption												
Elements and Satellite Testing												
Acoustics Testing												
Test Type (Acceptance / Protoflight / Qualification) => Duration												
Test Facility Energy Consumption												
Thermal Vacuum Testing												
Test Type (Acceptance / Protoflight / Qualification) => Duration												
Test Facility Energy Consumption												
Test Facility Nitrogen Consumption												
Vibrations Testing												
Test Type (Acceptance / Protoflight / Qualification) => Duration												
Test Facility Energy Consumption for Random Vibrations												
Test Facility Energy Consumption for Sine Vibrations												
Functional Testing												
Test Duration												
Element / Satellite Energy Consumption												
GSE Energy Consumption												
Test Facility HVAC Power Consumption												
Office Work / Travels												
Office Work												
System Integrator Collaborators												
"On site working" Workload (per site)												
"Home working" Workload (per country)												
Suppliers Collaborators												
"On site working" Workload (per site)												
"Home working" Workload (per country)												
Travels												
System Integrator Collaborators												
Plane Travels Distances												
Flight Types (national, international, intercontinental)												
Suppliers Collaborators												
Plane Travels Distances												
Flight Types (national, international, intercontinental)												
New Infrastructures (mandatory for program execution)												
New Infrastructures Construction and Dismantling												
System Integrator												
Building Type												
Building Surface												
Suppliers												
Building Type												
Building Surface												
New Infrastructures Equipment Manufacturing and Disposal												
System Integrator												
Dedicated Industrial Equipment Characteristics (type, quantity…)												
Dedicated Office Equipment (PCs…) characteristics (type, quantity…)												
Suppliers												
Launch Campaign												
Satellite Integration												
Transportation												
Integration Activities												

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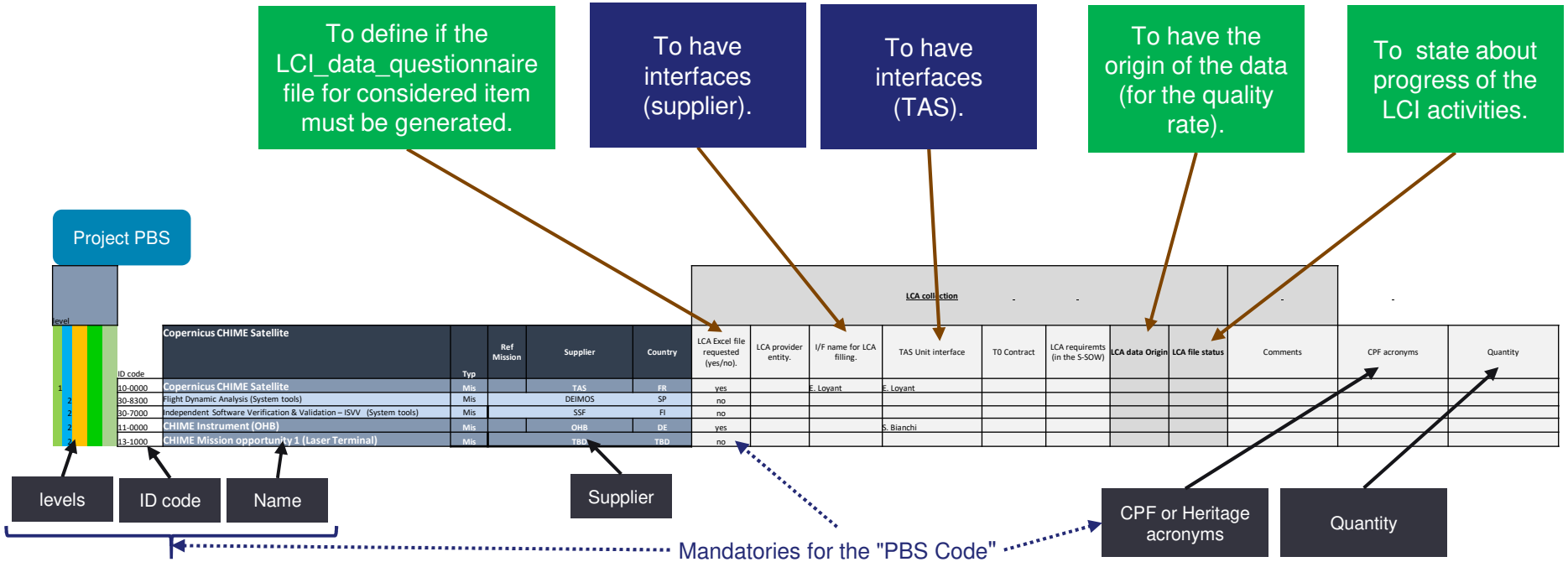
LCI / Questionnaires files preparation Code

/// With the following format the "PBS code" allows :



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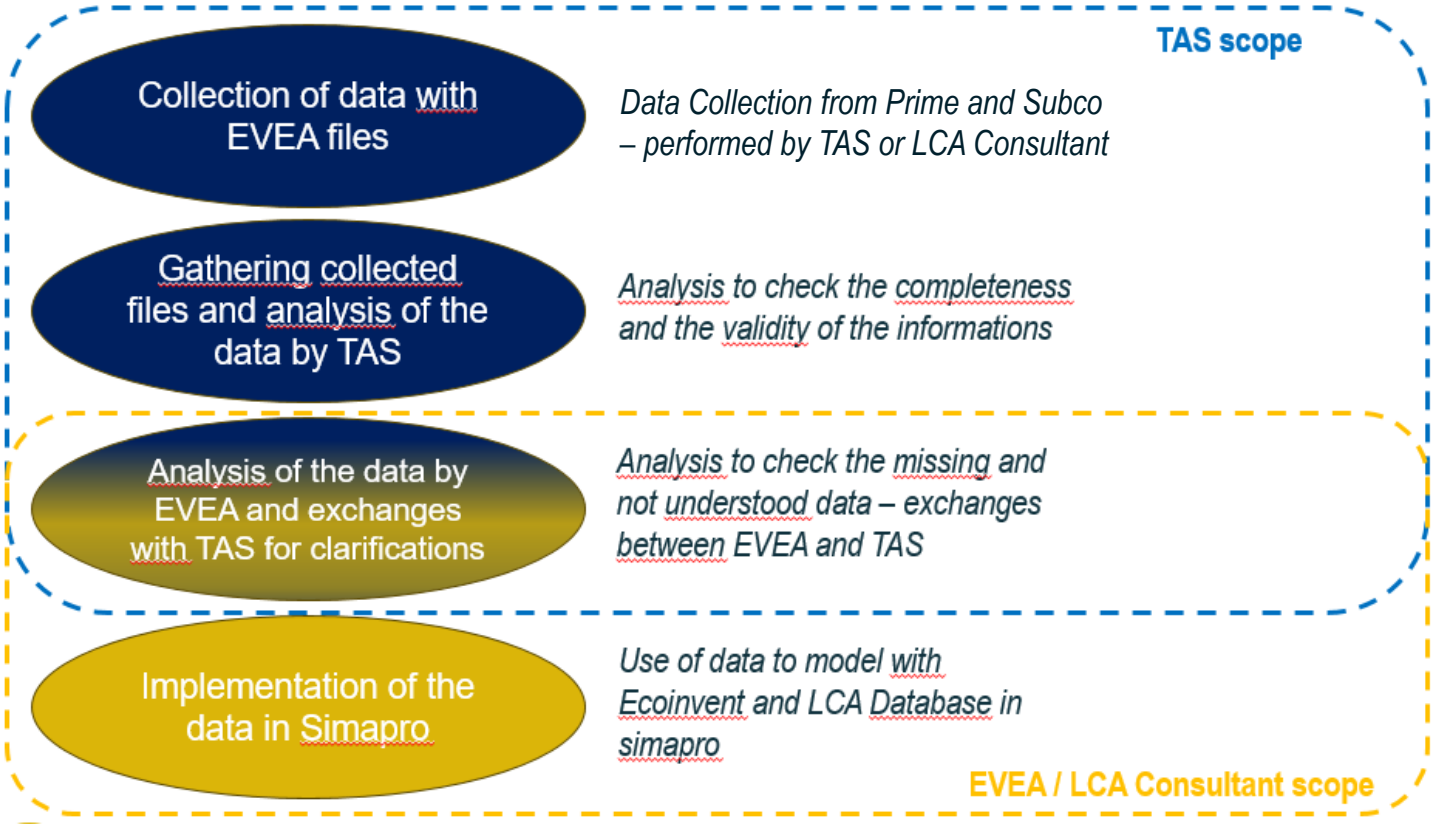
LCA / LCI Process



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LCI Data Collection Questionnaire File / Product Tree

Supplier	Acronyms	Year of the data	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Equipment	Part Number	ID Code	List of developed models related to the equipment (SM, STM, EM…)	Number of equipment in FM
ZZZ			SATELLITE									YYY-1234		
				SUBSYSTEM 1									1 QM, 1 PFM, 2 FM	1
					EQUIPMENT A								1 STM, 1 QM, 1 PFM, 2 FM	3
						COMPONENT A-1								
							ITEM A1-1							
							ITEM A1-2							
							ITEM A1-3							
						COMPONENT A-2								
							ITEM A2-1							
							ITEM A2-2							
							ITEM A2-3							
					EQUIPMENT B									
						COMPONENT 1								
							ITEM B1-1							
							ITEM B1-2							
					…									

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LCI Data Collection Questionnaire File / Materials

Supplier	Acronyms	Year of the data	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Equipment	Part Number	ID Code	List of developed models related to the equipment (SM, STM, EM…)	Number of equipment in FM	Element of the common plattform ? (yes/no)	Mission in charge of the collection	Mass of total equipment ? (level targeted) (kg)	Mass marging of level (%)	Material type	Percentage of mass or mass class (from DML) of material in one equipment	REACH material ? (yes or no)	CRM ? (yes or no)	Conflict mineral ? (yes or no)
3 Aerospace (ISTR		2023		STRUCTURE								ROSE-18000(	1 SM	1 PFM, 1 FM2, 1 FM3	no								
					PRIMARY STRUCTURE												111,00	20,0%					
						Lower Cone Assy											82,09	20,0%					
																			Al 7075 T7351	34%			
																			CFRP M55J / EX1515 or CFRP M46J / LY556 UD	56%			
																			HTA / LY556 Fabric (poxy resin CFRP)	1%			
																			Other materials for fasteners (Titanium)	9%			
						Upper Cylinder Assy											28,93	20,0%					
																			Al 7075 T7351	48,90%			
																			CFRP M46J / LY556 UD	39,40%			
																			HTA / LY556 Fabric	3,60%			
					SECONDARY STRUCTURE - Sandwich Panels												166,00	17%					
							Top Panel										14,58	17%					
																			CFRP Skins (EX1515 / M55J) + Aluminum Core (3/16-5056-.001p)	95%			
							Mid Panel Upper PXMY										5,85	17%					
							Mid Panel Upper MXMY										6,37	17%					
							Mid Panel Upper PY										4,34	17%					
							Mid Panel Lower PXMY										4,91	17%					
							Mid Panel Lower MXMY										4,82	17%					
							Mid Panel Lower PY										5,22	17%					
							Bottom Panel										14,01	17%					
							Pin Panel SAR Upper PXMY										0,78	17%					
							Pin Panel SAR Upper MXMY										0,78	17%					
							Pin Panel SAR Lower PXMY										0,78	17%					
							Pin Panel SAR Lower MXMY										0,78	17%					
							Pin Panel Solar Array Upper PY										0,74	17%					
							Bracing Panel Up PY Top										0,29	17%					
							Bracing Panel Up PY Bot										0,29	17%					
							Pin Panel Solar Array Lower PY										0,74	17%					
							Bracing Panel Low PY Top										0,29	17%					
							Bracing Panel Low PY Bot										0,29	17%					
							Shear Panel PXPY										6,66	17%					
							Shear Panel MXPY										7,26	17%					
							Shear Panel MY										6,09	17%					

From DML

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LCI Data Collection Questionnaire File / Manuf. Processes

1 Process (select from list)	1 Surface treatment (select from list)	1 Total scrap quantity (%)	1 Source of data	2 Process (select from list)	2 Surface treatment (select from list)	2 Total scrap quantity (%)	2 Source of data	3 Process (select from list)	3 Surface treatment (select from list)	3 Total scrap quantity (%)	3 Source of data	4 Process (select from list)	4 Surface treatment (select from list)	4 Total scrap quantity (%)	4 Source of data	5 Describe specifique process	5 Input Electricity consumption (kWh)	5 Input Heat consumption (MJ)	5 Water consumption (L)	5 Total scrap quantity (%)
Machining	Chromate Conversion Coating Surtec 650	30%		Drilling		15%		General metal working		20%		Threaded inserts and joints manufacturing on sandwich		5%						
Aluminum HC (Honeycomb Core) Manufacturing: [Corrugation of sheets + pressing + stacking + welding or Adhesive bonding +expansion]	Adhesive Bonding	10%		CFRP Skins prepreg Manufacturing: [dry carbon fabrics stacking + vacuum infusion technique/RTM-Resin Transfer Molding + room temperature curing + post-curing (80 C for 12 hrs)]	sanding	10%		Sandwich Manufacturing Process: [Bonding of Skins + HC with Adhesive + Lamination + Pressing at 10kPa + Curing @ 60 C for 35 mins + post curing @ room temperature]		5%		Drilling		15%						
	Adhesive Bonding			CFRP Skins prepreg Manufacturing: [dry carbon fabrics stacking + vacuum infusion technique/RTM-Resin Transfer Molding + room temperature curing + post-curing (80 C for 12 hrs)]	sanding	10%						Drilling		15%						
Machining		30%		Drilling		15%		General metal working Welding Additive manufacturing Composite manufacture Thermoforming Curing Extrusion Injection		20%										
Machining	Chromate Conversion	turning		Drilling				General metal working				Threaded inserts and joints								

- From DPL
- *Many Processes to be created ad-hoc since not present in Datasets as per Ecoinvent and ESA LCA DB*

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LCI Data Collection Questionnaire File / Transportation

Subcontractors and Lower-Tiers Transportation Data

Total distance to assembly site at equipment level (km)	**Transport type Travel 1** *(select from list)*	**Distance** Travel 1 (km)	**Transport type Travel 2** *(select from list)*	**Distance** Travel 2 (km)	**Transport type Travel 3** *(select from list)*	**Distance** Travel 3 (km)	**Use of GSE for transportation ?** (Yes/No)	**If Yes,** describe the GSE
7900		700	Road - Lorry				YES	Simple Transportation Boxes
7200	Road - Lorry						Yes	Transport Container

GIULIANI Marco:
All components of the FPFA are made by TAS-I in Rome - the 700 km distance takes account the shipping of parts from lower level manufactures, of sending parts to suppliers for particular treatments (it includes conservative margins)

GIULIANI Marco:
transportation of LBF from BEYOND GRAVITY from Goteborg - Sweden to Rome at TAS-I.
It also includes the shipping of the EM to TAS-I Rome for the EM testing of the FPFAS assembly and its shipping back to Beyond Gravity in Sweden for Vibration tests and Thermal Vacuum of LBF alone at Beyond Gravity

LCI Data Collection Questionnaire File / AIT Phase

Cleanroom Class [ISO 14644-1] Used for Assembly and Tests	Cleanroom Volume [m3]	HOURLY Cleanroom Energy Consumption (in operation) [KWh/hr]	AIT Activity detail	AIT Sub-Activity detail	Consumables	Assembly Duration in Cleanroom [hr]	Vibration Test Duration [hr]	HOURLY Energy Consumption during Vibration Test [KWh/hour]	Acoustic test Duration [hr]	Energy Consumption during Acoustic Test [KWh]	Acoustic Test Facility consumables	Acoustic Test activity detail	Thermal Vacuum Duration [hr]	Energy Consumption during Thermal Vacuum Test [KWh]	Consumption (e.g. LN2 for TV Chamber cooling) during TV/TB [m3/KWh or m3/h or m3/test]	EMC Test Duration [hr]	Energy Consumption during EMC Test [KWh]	EMC test details	Transportation by Airplane	Transportation by Lorry	Travelled Distance [km]	Transport Container Usage	Fluids and Consumables for Transportation
ISO 8			(SM) SM equipment/dummy masses integration on SM Structure			120																	
ISO 8			(SM) SM1 Antenna SM (FEMD)			40																	
ISO 8			(SM) ALIGNMENTS			40																	
ISO 8			(SM) MASS			24																	
ISO 8 TAS-I Rome Test Centre			(SM) Sine Vibration Test		315 accelerometers (standard + special for shock) + 35 strain gauges	208	6	2,4															
ISO 8 TAS-I Rome Test Centre			(SM) Acoustic Noise Test		TBD Accelerometers	126			6	400													
ISO 8 TAS-I Rome Test Centre			(SM) Launcher fit check and separation shock test		40 shock accelerometers	88																	
ISO 8			(SM) Alignment check			40																	
ISO 8			(SM) Dummy mass dismounting			88																	
TRANSPORTATION																				SM model shipment to SAB in Brno (CZ) (for STM FM2)	1300	Simple TC	N/A
ISO 8			(PFM) EGSE			160																	
ISO 8			(PFM) S/C STRUCTURE PREPARATION			160																	
ISO 8			(PFM)			80																	
ISO 8			(PFM) PLATFORM																				
ISO 8			(PFM)	Harness Integration		120																	
ISO 8			(PFM)	hermal HW integration		16																	
ISO 8			(PFM)	DU Integration & Test		40																	
ISO 8			(PFM)	SMU NG		40																	
ISO 8			(PFM)	RTU Integration &		8																	
ISO 8			(PFM)	CSS Integration &		8																	
ISO 8			(PFM)	Star tracker		8																	
ISO 8	5400	135,4166667	(PFM)	Magnetometer		8																	
ISO 8			(PFM)	Magnetorquer		8																	
ISO 8			(PFM)	Reaction Wheel		8																	
ISO 8				Gyro Integration &		8																	
ISO 8				Camera FE		8																	
ISO 8				TTC Integration & Test (except SBA)	GN2 (300 liters), GHe (300 liters), Demineralized Water (100 liters)	8																	
ISO 8				Battery Panel Integration	-315 accelerometers (standard + special for shock) - 35 strain gauges - water (200 liters TBC) to pressurize tanks	8																	
ISO 8			(PFM) Integrated Subsystem Test ISST		- water (200 liters TBC) to pressurize tanks	240																	

- *Energy, Fluids Consumptions derived from Companies monthly Monitoring campaign as per ISO 50001 compliance*
- *Proper Country Energy mix assigned*

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LCI Data Collection Questionnaire File / AIT Phase

Cleanroom Class [ISO 14644-1] Used for Assembly and Tests	Cleanroom Volume [m3]	HOURLY Cleanroom Energy Consumption (in operation) [KWh/hr]	AIT Activity detail	AIT Sub-Activity detail	Consumables	Assembly Duration in Cleanroom [hr]	Vibration Test Duration [hr]	HOURLY Energy Consumption during Vibration Test [KWh/hour]	Acoustic test Duration [hr]	Energy Consumption during Acoustic Test [KWh]	Acoustic Test Facility consumables	Acoustic Test activity detail	Thermal Vacuum Duration [hr]	Energy Consumption during Thermal Vacuum Test [KWh]	Consumption (e.g. LN2 for TV Chamber cooling) during TV/TB [m3/KWh or m3/h or m3/test]	EMC Test Duration [hr]	Energy Consumption during EMC Test [KWh]	EMC test details	Transportation by Airplane	Transportation by Lorry	Travelled Distance [km]	Transport Container Usage	Fluids and Consumables for Transportation
ISO 8			(PFM) PDHT Integration, Test & ISST	- water (200 liters TBC) to pre		120																	
ISO 8			(PFM) Instrument Back End Integration, Test & ISST			80																	
ISO 8			(PFM) Integrated			176																	
ISO 8			(PFM) System			80																	
ISO 8			(PFM) Alignment (before TVAC)			80																	
ISO 8 TAS-I Rome Test Centre			(PFM) TB/TVAC		350 (TBC) thermocouples								924	1,152777778									
ISO 8			(PFM) Instrument			200																	
ISO 8			(PFM) KBA + SBA			40																	
ISO 8			(PFM) CAM			32																	
ISO 8			(PFM) Solar Array Mass Inertia (if			120							1065,166667										
ISO 8			(PFM) Preparation and Shipment to External Facility (TBC)			40																	
TRANSPORTATION																				Transportation to External Facility for TESTS (facility TBD)	1600	Transport Container / ISO 8 conditions / Flushed and pressurized with GN2	100 liters GN2
ISO 8 ESTEC			(PFM) Mass properties Measurement (incl. Simulant loading)			40																	
ISO 8 ESTEC			(PFM) Vibration Test		314 accelerometers + 35 strain gauges, + 133kg water or IPA (pressurized at 22 bar to fill the tank)	120	6	2,4															
ISO 8 ESTEC			(PFM) Acoustic Test		TBD accelerometers (standard + 133kg water or IPA (pressurized at 22 bar to fill the tank)	80			8	1000 KWh per test	-GN2 - 2000 liters TBC - 1000 liters of water TBC												
ISO 8 ESTEC			(PFM)Launcher Fit-Check and Sep Shock (incl. Simulant loading)		GN2 (300 liters), GHe (300 liters), Demineralized Water or IPA (100 liters) + 40 shock accelerometers	40																	
ISO 8 ESTEC			(PFM)Alignment			80																	
ISO 8 ESTEC			(PFM) Solar Array Dismounting			16																	
ISO 8 ESTEC	2400	135,41	(PFM) Integrated Spacecraft Test IST 2 Stowed			80																	

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LCI Data Collection Questionnaire File / AIT Phase

Cleanroom Class [ISO 14644-1] Used for Assembly and Tests	Cleanroom Volume [m3]	HOURLY Cleanroom Energy Consumption (in operation) [KWh/hr]	AIT Activity detail	AIT Sub-Activity detail	Consumables	Assembly Duration in Cleanroom [hr]	Vibration Test Duration [hr]	HOURLY Energy Consumption during Vibration Test [KWh/hour]	Acoustic test Duration [hr]	Energy Consumption during Acoustic Test [KWh]	Acoustic Test Facility consumables	Acoustic Test activity detail	Thermal Vacuum Duration [hr]	Energy Consumption during Thermal Vacuum Test [KWh]	Consumption (e.g. LN2 for TV Chamber cooling) during TV/TB [m3/KWh or m3/h or m3/test]	EMC Test Duration [hr]	Energy Consumption during EMC Test [KWh]	EMC test details	Transportation by Airplane	Transportation by Lorry	Travelled Distance [km]	Transport Container Usage	Fluids and Consumables for Transportation
ISO 8 ESTEC			(PFM) Instrument Front End Deployment & test			120																	
ISO 8 ESTEC			(PFM) EMC CE/CS			80																	
Anechoic Chamber			(PFM)RFC Test (Autocompatibility and RE/RS)			120										(120)	all energy consumption for EGSEare embedded in "Cleanroom " energy consumption (column "CK")						
ISO 8 ESTEC			(PFM) System Validation Test SVT-3			80																	
ISO 8 ESTEC			(PFM) Alignment check			40																	
ISO 8 ESTEC			(PFM) Integrated Spacecraft Test (IST-2)			80																	
ISO 8 ESTEC			(PFM) Solar Array Integration and Electrical Integration and Alignment			56																	
ISO 8 ESTEC			(PFM) System Validation Test SVT-4			40																	
ISO 8 ESTEC			(PFM) Propulsion Final Test			80																	
ISO 8 ESTEC			(PFM) Satellite Preparation and shipment to Launch Site (opt.)			40																	
TRANSPORTATION																			Transportation to Airport and from arrival to Launch site		42	Shipping Transportation Container (GN2 flushed, ISO 8 EnvirOnment)	100 liters GN2
TRANSPORTATION																		Transportation to Kourou Launch Site			10800	Shipping Transportation Container (GN2 flushed, ISO 8 EnvirOnment)	101 liters GN2
Launch Site ISO 8 Cleanroom	3000	150	(PFM) Launch Preparation Activities, Launch Campaign (including Propellant Loading)			480																	

TOTAL PFM AIT	TOTAL PFM VIBRATION Test		TOTAl PFM ACOUSTIC TEST				TOTAL PFM TVTB TEST			TOTAL PFM EMC Test				TOTAl PFM Lorry Transportation	Total PFM Airplane Transportation		
5274	12		14				924			see comment				2942	10800		

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LCI Questionnaire File / Office Work & Travels

Satellite Model type	Number of traveling employees (nbr)	Average distance of aircraft travels (km)	Total of number of employees in the site in a year (nbr)	Number of working employees on satellite project in a year (nbr)	Number of hours worked in a year (hours)	Energy consumption of the site in a year (kWh)	Water consumption of the site in a year (L)	Number of years to developper the product (nbr)
PFM								
FM								

LCI / Methodological Limitations

- LCI Questionnaires partially compiled or filled with estimated data
  - **Raw materials sources** and origin info very **difficult to be retrieved**
    - Literature (and Global Ecoinvent) data used as workaround solution
  - **Scraps and Processing wastes poorly known** even by process owners
  - Very time-consuming

- **Lack of maturity of** the entire **supply chain** in the management of Life Cycle Inventory information
  - "LCI Workshops" held by Prime to instruct Subcos
    - All Key roles and supporting functions have been/are being trained

- Systematic and organized processes for collecting the required data are not yet in place at all levels of the Supply Chain

- LCI Questionnaires refinement for 2nd LCA Iteration based on:
  - Priority List based on DQR computation
  - Mass cut-off criterion
  - Cost cut-off criterion

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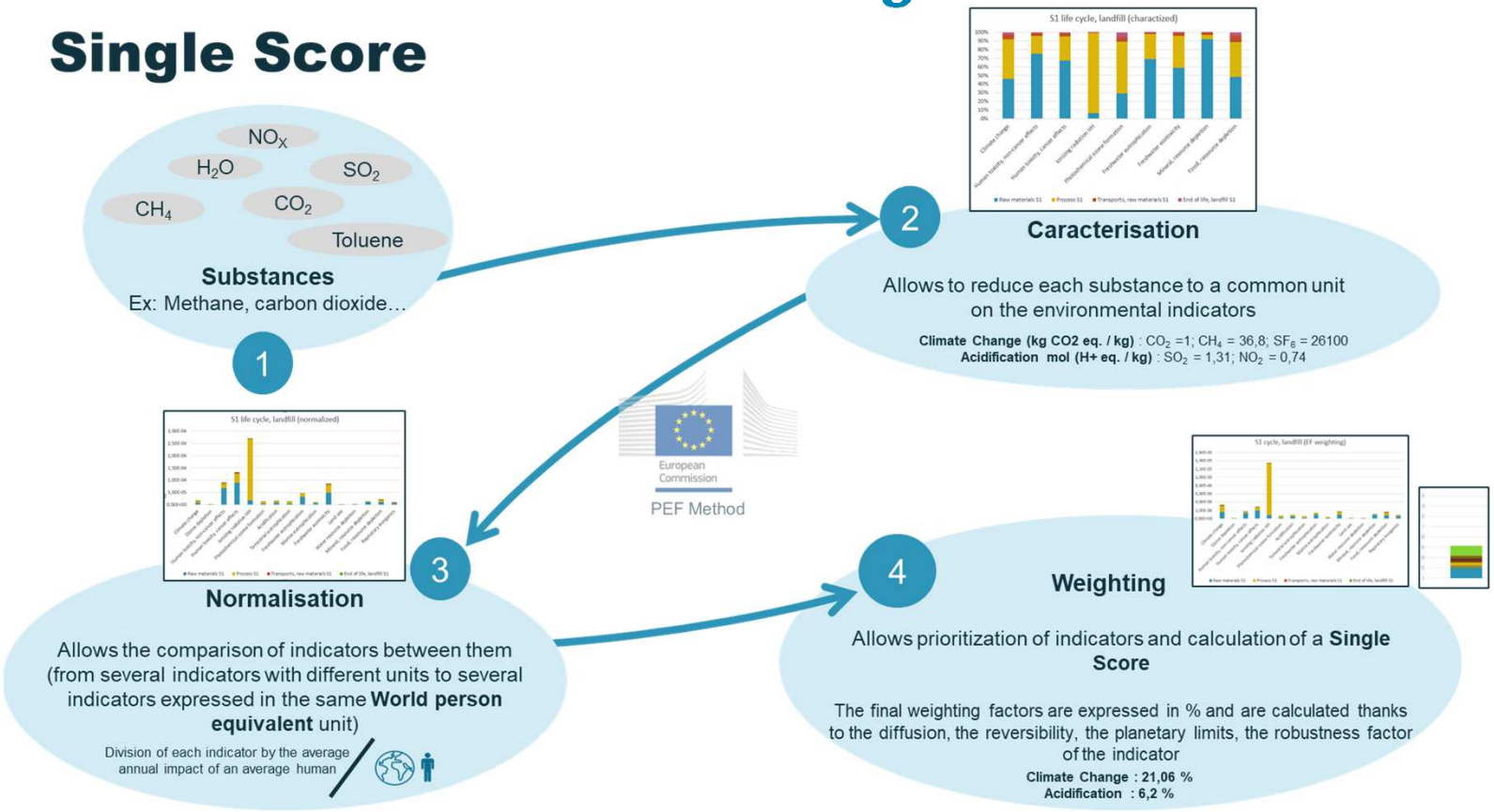
LCIA / Selected Indicators – Single Score

Single Score



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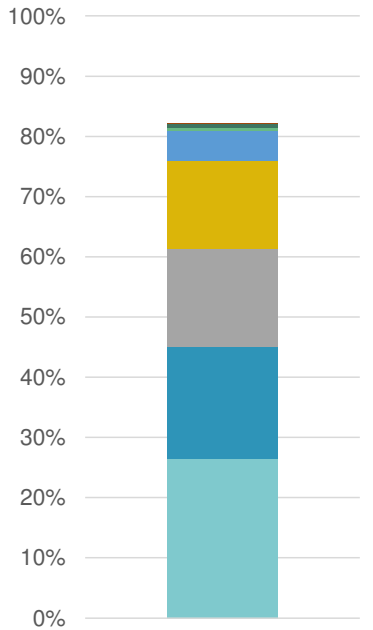
LCIA / Selected Indicators – Single Score

The choice of indicators is based on the PEF methodology:
At least 8 indicators are selected, contributing more than 80% of the average cumulative impacts to the single score on the full assembly

Impact indicators	Unit	Robustness I: robust III: not very robust	Description
Climate Change 26.4%	kg CO_2 eq	I	Takes into account greenhouse gas emissions (CO2, methane, ...) that contribute to global warming over a time horizon of 100 years.
Resource use, fossils 18.7%	MJ	III	Characterizes the depletion of the environment of non-renewable fossil fuels such as natural gas, coal, oil, etc.
Ecotoxicity 16.4%	CTUe	II / III	Characterizes pollutants released into the aquatic environment (heavy metals, cyanide, etc.) when discharged into water.
Resource use, minerals and metals 14.5%	kg Sb eq	III	Characterizes the contribution to the depletion of accessible and exploitable mineral and metal resources.
Water use 4.9 %	m3 depriv.	III	Characterizes the depletion potential of available freshwater resources, taking into account their scarcity according to geography.
Human toxicity 1.1%	CTUh	III	This impact category concerns the effects of toxic substances on human health. The diversity of molecules, their modes of action and the damage caused as a function of exposure, the effects of indirect exposure and cocktail effects represent such a degree of complexity that this impact category is one of the most difficult to model.
Ozone depletion 0.2%	kg CFC – 11 eq	I	Includes all substances that contribute to stratospheric ozone depletion.



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LCIA / DQR

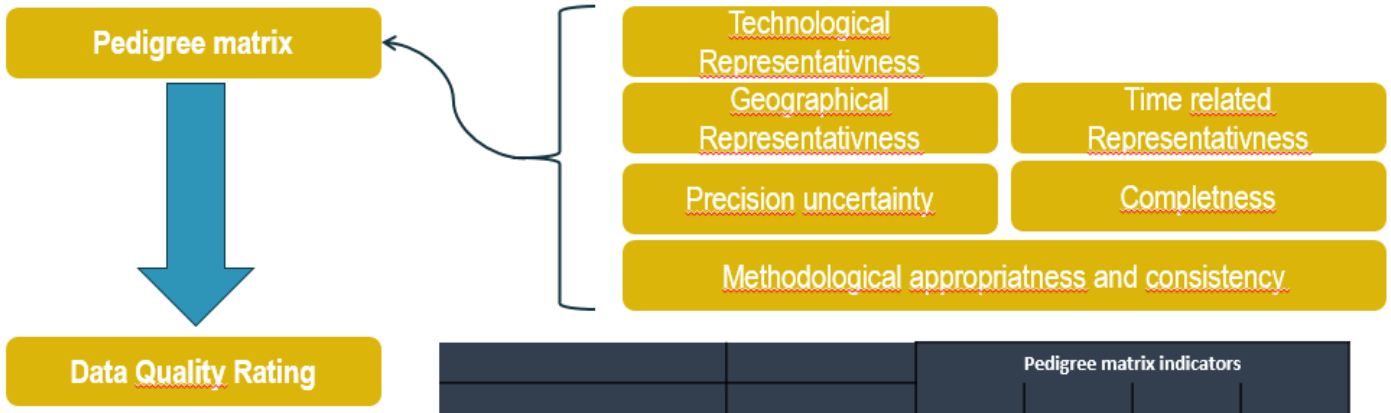
A Quality Indicator Rating (QIR) has been allocated to each modelled component and separately for each of the following Quality Indicators (QIs):

- **[TeR]** - Technological representativeness
- **[GR]** – Geographical representativeness
- **[TiR]** - Time-related representativeness
- **[C]** – Completeness
- **[P]** – Precision/uncertainty
- **[M]** - Methodological appropriateness and consistency

A DQR is calculated only for “DQR-eligible” QIs for which at least one model dataset has a QIR > 3 and typically from the following Impact Categories standpoint:

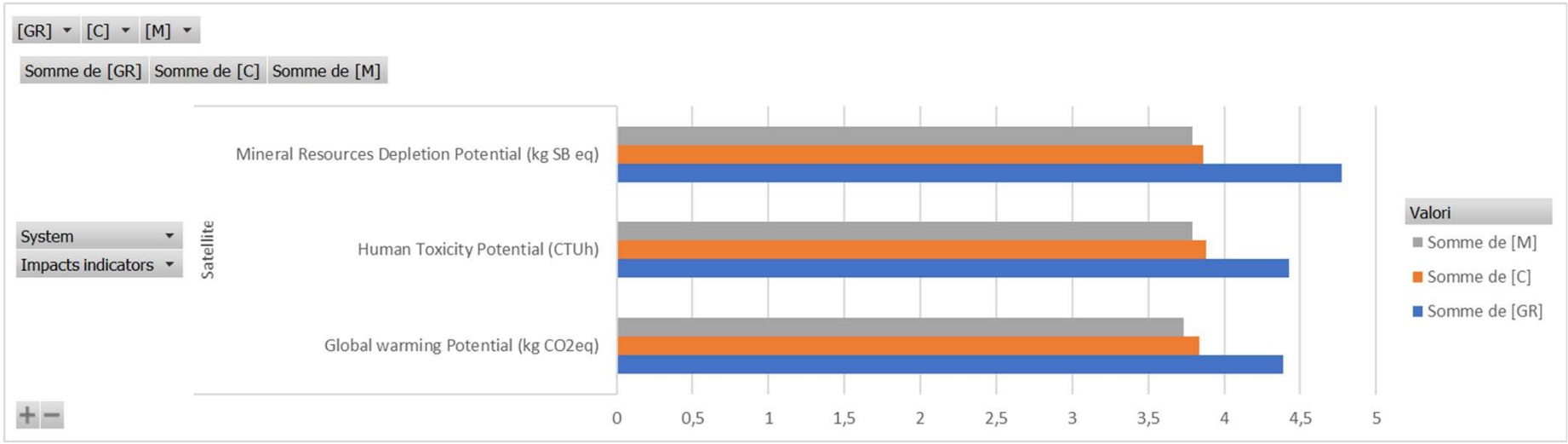
- Global Warming Potential (**GWP**)
- Abiotic Resource Depletion Potential - Elements/Minerals (**ADEPLm**)
- Human Toxicity Potential (**HTP**)
- Air Acidification Potential (**ACID**)
- Particular Matter Formation Potential (**PMAT**)
- Gross Water Consumption Potential (**WDEPL**)

LCIA /DQR



System	Impacts indicators	Pedigree matrix indicators [TeR]	[GR]	[C]	[P]
ROSE-L Satellite	*Global warming Potential (kg CO2eq)*	1,90	5,00	1,56	2,00
	Mineral Resources Depletion Potential (kg SB eq)	2,02	5,00	1,48	2,01
	Human Toxicity Potential (CTUh)	1,46	5,00	1,24	2,00

LCIA /DQR



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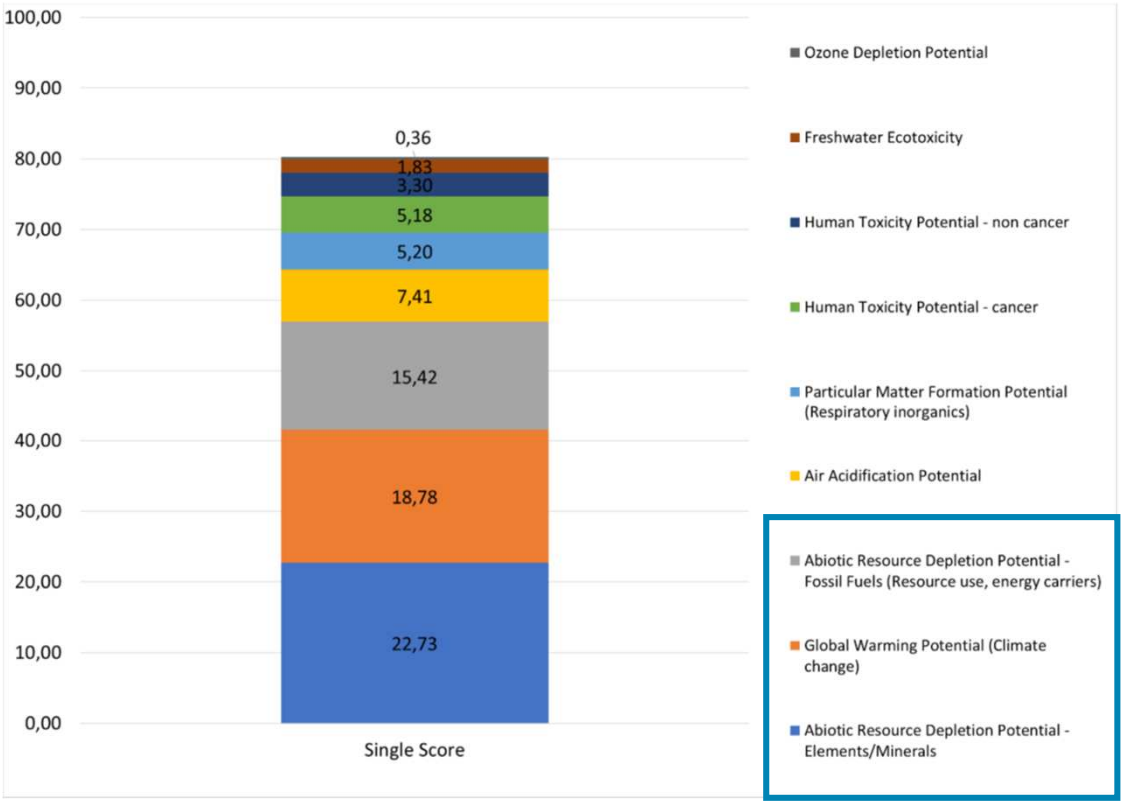
LCIA / Results – Single Score



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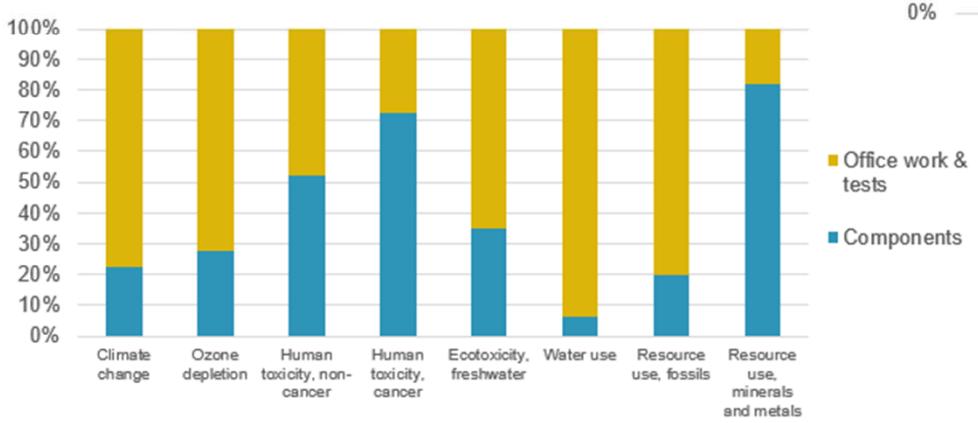
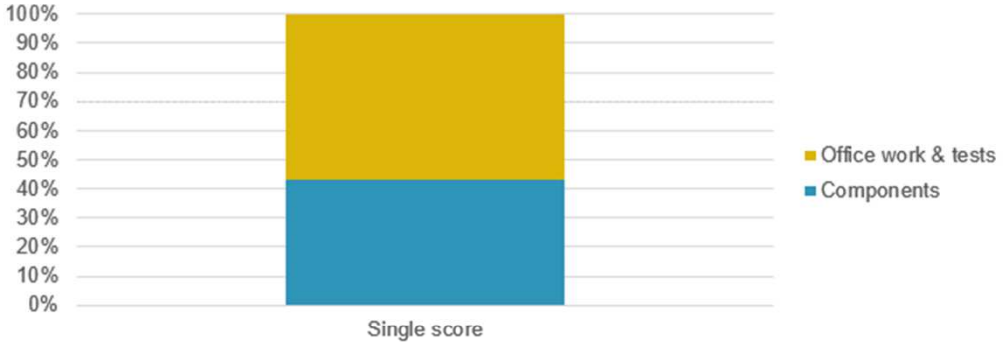
LCIA / Results – Single Score

Major part of the environmental contribution of the ROSE-L project, through the single score, comes from the steps of **office working and testing (57% of the single score)**. The **components (raw materials and manufacturing)** represent **43% of the single score**.





This difference is mainly due to differences in impact on the **climate change** and **resource use, fossils** indicators. This is explained by the **electricity mix of most of European country**, which contains a high proportion of **coal and gas fired power**.

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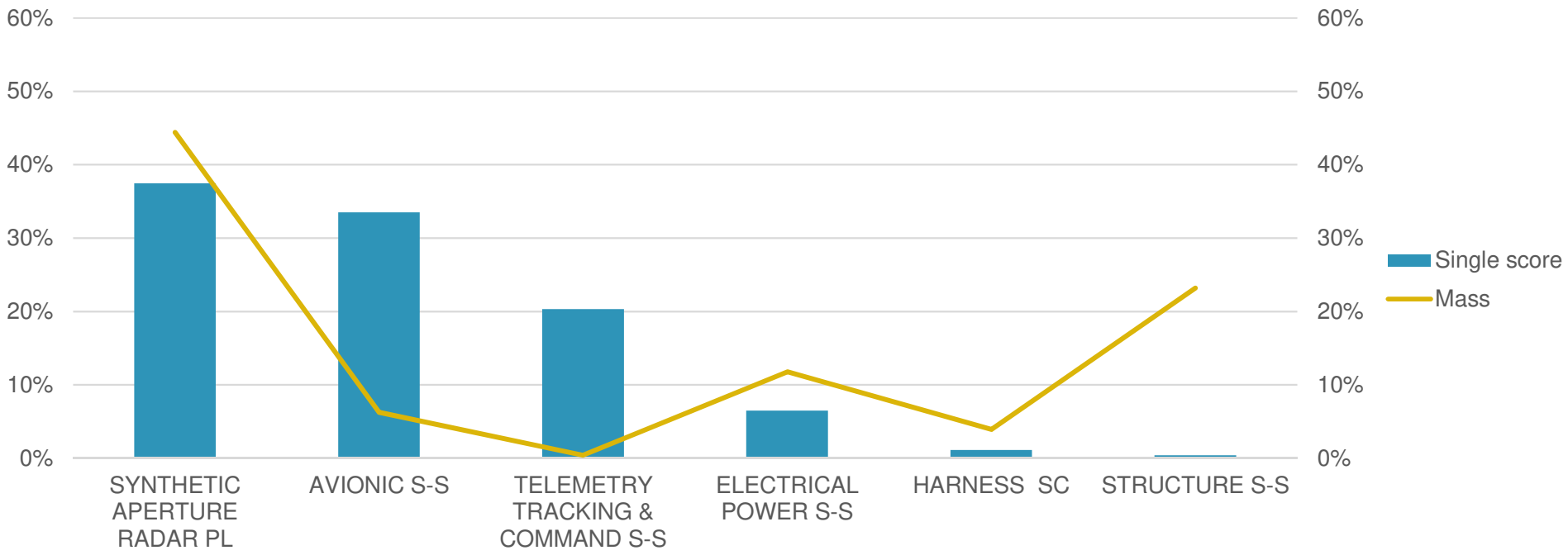
LCIA / Results – Single Score



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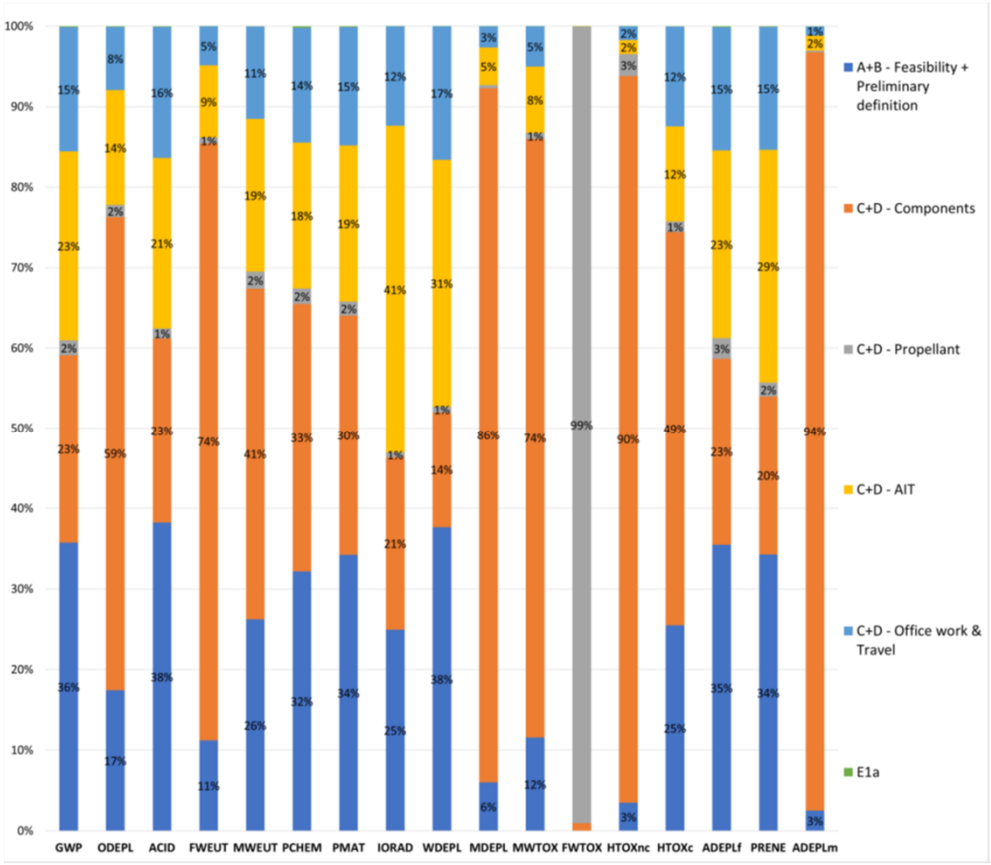
LCIA / Results – Single Score



Predominance of the C+D phase – (production and manufacturing of components), including the extraction and processing of raw materials, for many impact categories (9 out of 17 in the example).

For 6 out of 17 impact categories the biggest contribution is given by A+B phase (“Climate change”, “Air acidification”, “Particulate matter”, “Gross water consumption”, “Abiotic Resource Depletion”, “Primary Energy Consumption

For A+B phases, Energy and Water consumption represent the **main source of impacts**.
Same for C+D-AIT -Cleanroom and C+D office work & travel (FM model).

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Ecodesign / Thales Tools : CLOE

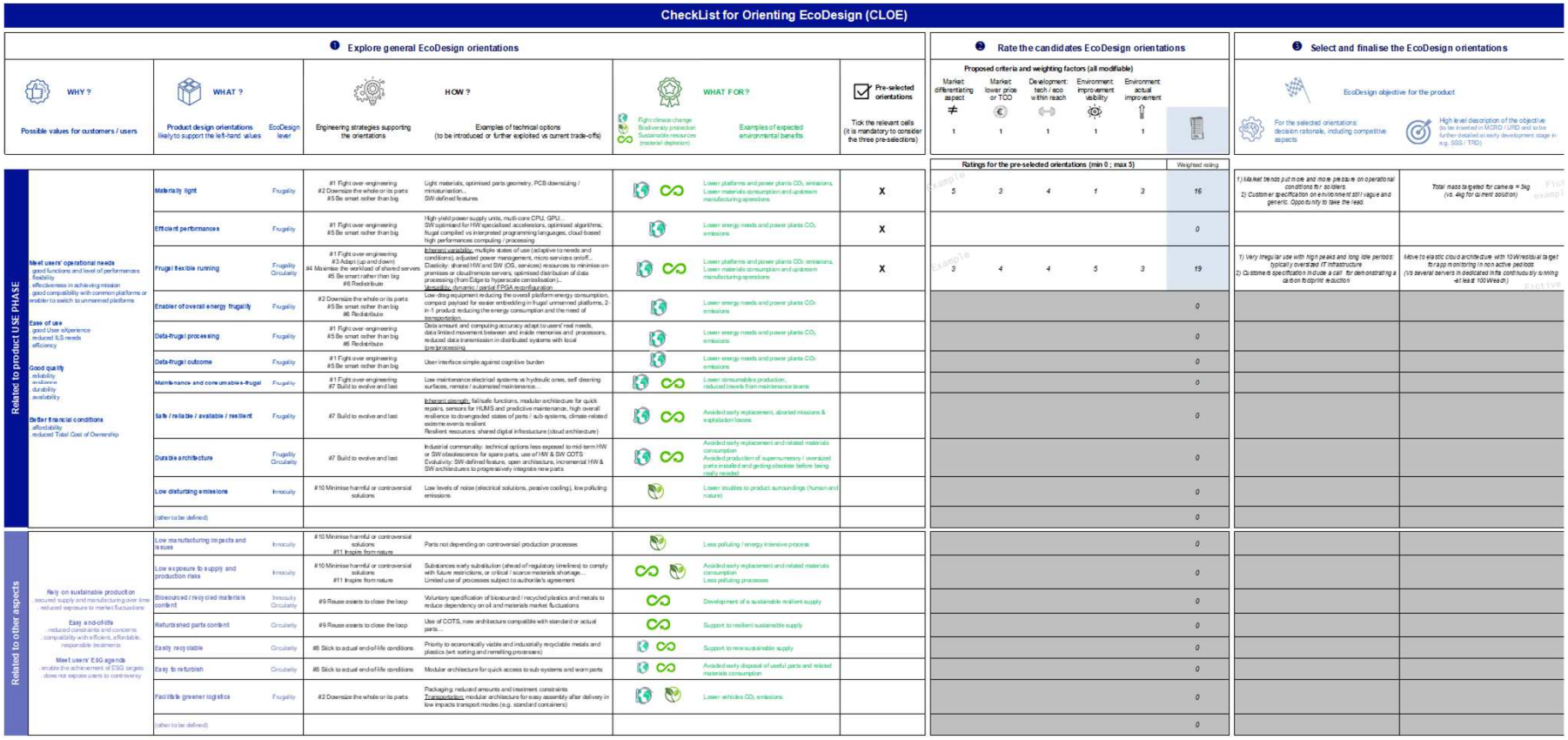
Thales Tool: **CLOE** – **C**heck**L**ist for **O**rienting **E**codesign – Matrix

- To set proper orientations for Thales solutions before the launch of the product and in line with Customers' stakes;
- Conceived for Product Definition Leaders (PLM, PLA);
- Keeps track of the rationale, not only the requirements;
- Combines elements to describe ecodesign orientations and to help to take decisions;
- →to aim not only at Good products but to Good AND GREEN products

Explore possible orientations:

- Section1: explores users viewpoint with the possible sources of value, technical illustrations of what it could mean for the product and the expected environmental benefit;
- Section 2 offers a rating of the ecodesign orientations preselected in section 1, rating is based on criteria and weighting factors that can be modified;
- Section 3 records the decision taken by the leaders and transforms them in requirements

Ecodesign / Thales Tools : CLOE



CheckList for Orienting EcoDesign (CLOE)

❶ Explore general EcoDesign orientations							❷ Rate the candidates EcoDesign orientations							❸ Select and finalise the EcoDesign orientations	
WHY ? Possible values for customers / users	WHAT ? Product design orientations (ie/y/s to support the left-hand values	EcoDesign lever	HOW ? Engineering strategies supporting the orientations	Examples of technical options (to be introduced or further exploited vs current trade-offs)	WHAT FOR ? Examples of expected environmental benefits	Pre-selected orientations Tick the relevant cells (it is mandatory to consider the three pre-selections)	Proposed criteria and weighting factors (all modifiable): Market differentiating aspect (≠)	Market lower price or TCO (€)	Development: tech / eco within reach	Environment improvement visibility	Environment actual improvement		Ratings for the pre-selected orientations (min 0 ; max 5)	Weighted rating	EcoDesign objective for the product: For the selected orientations: decision rationale, including competitive aspects	High level description of the objective (to be inserted in MCRD / URD and to be further detailed at early development stage in: e.g. SSS / TRD)
							1	1	1	1	1				
Related to product USE PHASE															
Meet users' operational needs: good functions and level of performances; flexibility; effectiveness in achieving mission; good compatibility with common platforms or enabler to switch to unmanned platforms	Materially light	Frugality	#1 Right over-engineering; #2 Downsize the whole or its parts; #5 Be smart rather than big	Light materials, optimised parts geometry, PCB downsizing / miniaturisation... SW-defined features	Lower platforms and power plants CO_2 emissions; Lower materials consumption and upstream manufacturing operations	X	Example: 5	3	4	1	3		16	1) Market trends put more and more pressure on operational conditions for soldiers; 2) Customer specification on environment still vague and generic. Opportunity to take the lead.	Total mass targeted for camera = 3kg (vs. 4kg for current solution)
	Efficient performances	Frugality	#1 Right over-engineering; #5 Be smart rather than big	High yield power supply units, multi-core CPU, GPU... SW optimised for HW specialised accelerators, optimised algorithms, frugal compiled vs interpreted programming languages, cloud-based high performances computing / processing	Lower energy needs and power plants CO_2 emissions	X							0		
	Frugal flexible running	Frugality; Circularity	#1 Right over-engineering; #3 Adapt (up and down); #4 Maximise the workload of shared servers; #5 Be smart rather than big; #6 Redistribute	Inherent variability: multiple states of use (adaptive to needs and conditions), adjusted power management, micro-services on/off... Elasticity: shared HW and SW (OS, services) resources to minimise on-premises or cloud/remote servers, optimised distribution of data processing (from Edge to hyperscale centralisation)... Versatility: dynamic / partial FPGA reconfiguration	Lower platforms and power plants CO_2 emissions; Lower materials consumption and upstream manufacturing operations	X	Example: 3	4	4	5	3		19	1) Very irregular use with high peaks and long idle periods: typically oversized IT infrastructure; 2) Customer specification include a call for demonstrating a carbon footprint reduction	Move to elastic cloud architecture with 10W/residual target for app monitoring (+ non active periods) (Vs several servers in dedicated HW continuously running at least 100W each)
Ease of use: good User eXperience; reduced ILS needs; efficiency	Enabler of overall energy frugality	Frugality	#2 Downsize the whole or its parts; #5 Be smart rather than big; #6 Redistribute	Low-drag equipment reducing the overall platform energy consumption, compact payload for easier embedding in frugal unmanned platforms, 2-in-1 product reducing the energy consumption and the need of transportation...	Lower energy needs and power plants CO_2 emissions								0		
	Data-frugal processing	Frugality	#1 Right over-engineering; #5 Be smart rather than big; #6 Redistribute	Data amount and computing accuracy adapt to users' real needs, data limited movement between and inside memories and processors, reduced data transmission in distributed systems with local (pre)processing	Lower energy needs and power plants CO_2 emissions								0		
Good quality: reliability; resilience; durability; availability	Data-frugal outcome	Frugality	#1 Right over-engineering; #5 Be smart rather than big	User interface simple against cognitive burden	Lower energy needs and power plants CO_2 emissions								0		
	Maintenance and consumables-frugal	Frugality	#1 Right over-engineering; #7 Build to evolve and last	Low maintenance electrical systems vs hydraulic ones, self cleaning surfaces, remote / automated maintenance...	Lower consumables production, reduced travels from maintenance teams								0		
Better financial conditions: affordability; reduced Total Cost of Ownership	Safe / reliable / available / resilient	Frugality	#7 Build to evolve and last	Inherent strength: fail-safe functions, modular architecture for quick repairs, sensors for HUMS and predictive maintenance, high overall resilience to downgraded states of parts / sub-systems, climate-related extreme events resilient; Resilient resources: shared digital infrastructure (cloud architecture)	Avoided early replacement, aborted missions & exploitation losses								0		
	Durable architecture	Frugality; Circularity	#7 Build to evolve and last	Industrial commonality: technical options less exposed to mid-term HW or SW obsolescence for spare parts, use of HW & SW COTS; Evolutivity: SW-defined feature, open architecture, incremental HW & SW architectures to progressively integrate new parts	Avoided early replacement and related materials consumption; Avoided production of supernumerary / oversized parts installed and getting obsolete before being really needed								0		
	Low disturbing emissions	Innocuity	#10 Minimise harmful or controversial solutions	Low levels of noise (electrical solutions, passive cooling), low polluting emissions	Lower troubles to product surroundings (human and nature)								0		
	(other to be defined)												0		
Related to other aspects															
Rely on sustainable production: secured supply and manufacturing over time; reduced exposure to market fluctuations	Low manufacturing impacts and issues	Innocuity	#10 Minimise harmful or controversial solutions; #11 Inspire from nature	Parts not depending on controversial production processes	Less polluting / energy intensive process								0		
	Low exposure to supply and production risks	Innocuity	#10 Minimise harmful or controversial solutions; #11 Inspire from nature	Substances early substitution (ahead of regulatory timelines) to comply with future restrictions, or critical / scarce materials shortage... Limited use of processes subject to authorité's agreement	Avoided early replacement and related materials consumption; Less polluting processes								0		
Easy end-of-life: reduced constraints and concerns; compatibility with efficient, affordable, responsible treatments	Biosourced / recycled materials content	Innocuity; Circularity	#9 Reuse assets to close the loop	Voluntary specification of biosourced / recycled plastics and metals to reduce dependency on oil and materials market fluctuations	Development of a sustainable resilient supply								0		
	Refurbished parts content	Circularity	#9 Reuse assets to close the loop	Use of COTS, new architecture compatible with standard or actual parts...	Support to resilient sustainable supply								0		
	Easily recyclable	Circularity	#6 Stick to actual end-of-life conditions	Priority to economically viable and industrially recyclable metals and plastics (wrt sorting and remelting processes)	Support to more sustainable supply								0		
Meet users' ESG agenda: enable the achievement of ESG targets; does not expose users to controversy	Easy to refurbish	Circularity	#6 Stick to actual end-of-life conditions	Modular architecture for quick access to sub-systems and worn parts	Avoided early disposal of useful parts and related materials consumption								0		
	Facilitate greener logistics	Frugality	#2 Downsize the whole or its parts	Packaging: reduced amounts and treatment constraints; Transportation: modular architecture for easy assembly after delivery in low impacts transport modes (e.g. standard containers)	Lower vehicles CO_2 emissions								0		
	(other to be defined)												0		

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THALES
ThalesAlenia Space

Ecodesign / Thales Tools : PETER

Thales Tool: **PETER: P**roduct **E**valuation **T**ool for **E**coDesign and **R**eporting

- internal tool that was developed to evaluate CO_2 emissions in a product's Life Cycle
  → at the end the user gets the key trends in CO_2 emissions over the product life cycle

- Addresses the three main phases of product lifecycle:
  - Manufacturing (materials breakdown of mechanical parts and electronics, testing, qualification);
  - Use (in-use mobility, in-use power consumption)
  - End of life (including recycling)

- A convenient alternative to complex lifecycle assessment tools

- To be used before starting or at the very beginning of product development or to understand basic environmental trends of an existing solution

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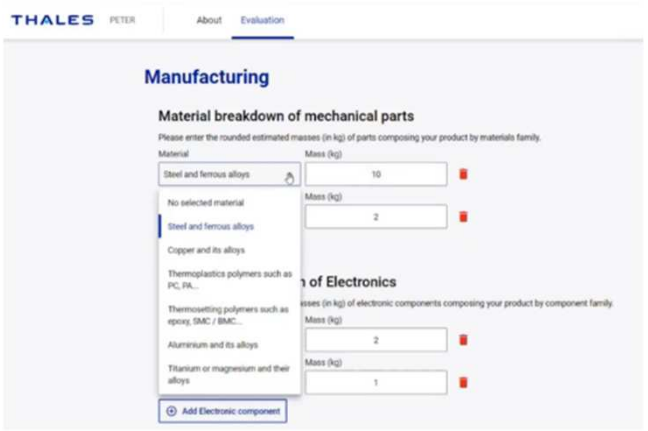
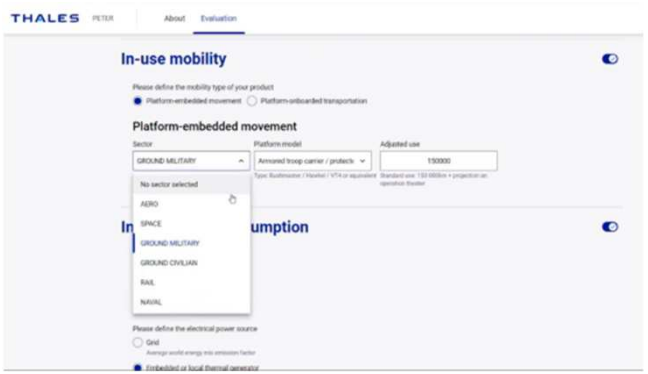
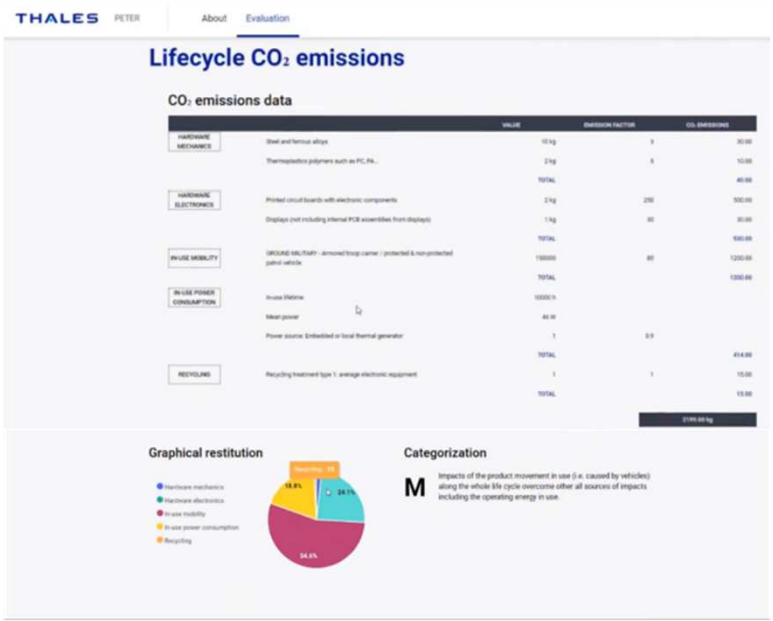
Ecodesign / Thales Tools : PETER







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Conclusions / LCA Future Outlook

- Need for a "**Backward LCA**" process: systematic collection and analysis of environmental impact results to identify most critical materials and processes to start re-thinking DML and DPL in a greener but space qualified way;

- Need to **contextualize** the Space Sector LCA results **wrt Planetary Boundaries** and to balance the global markets environmental impacts
  - To avoid in the future too strict requirements if Space Segments environmental impact is small if compared to other segments/sectors

- Need to include in System Level LCA also the **Downstream Usage** of Space Missions (User Segment)
  - Users Telecomms Terminals, EO Data post-processing, GNSS receivers

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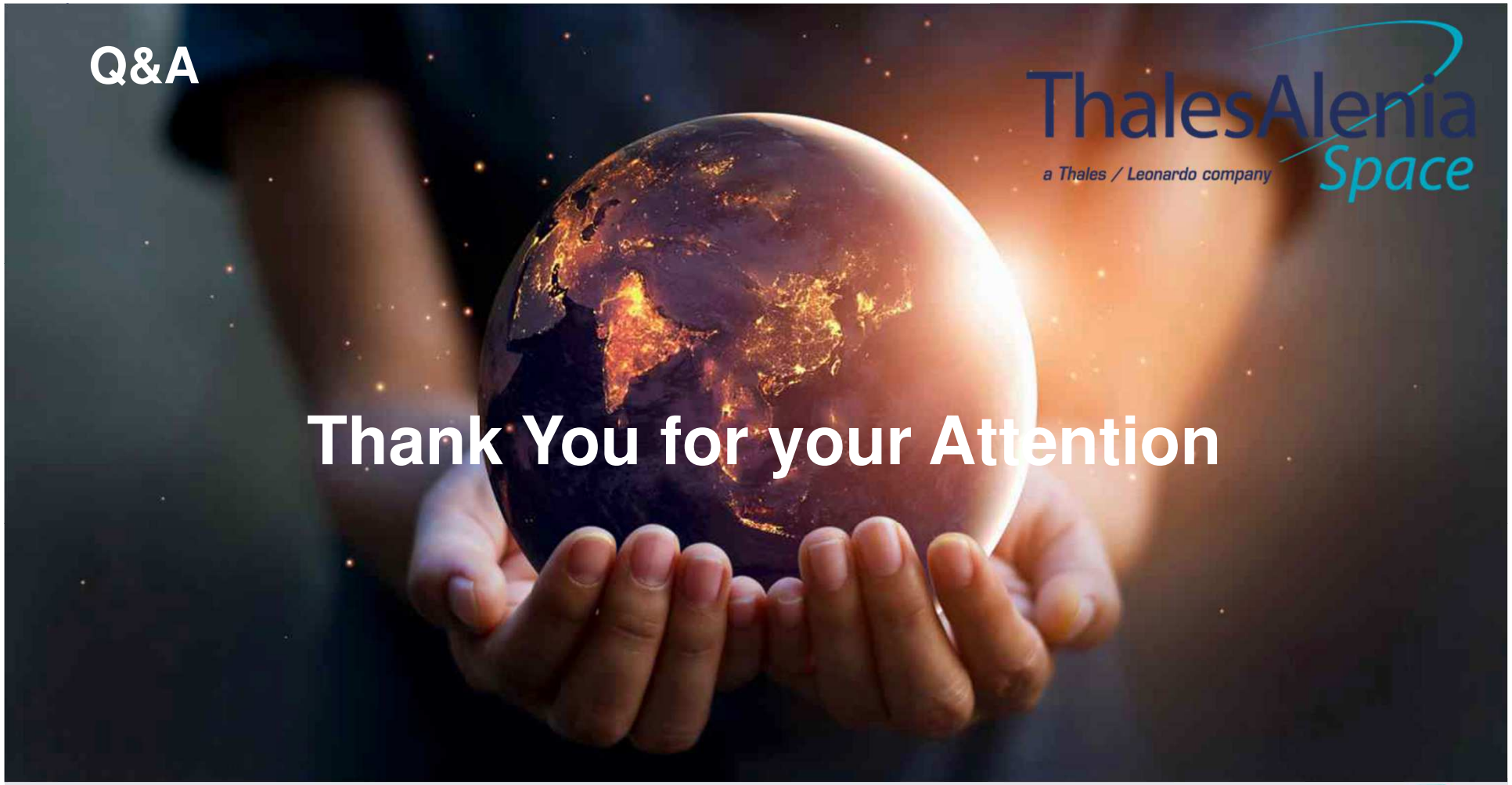
Q&A



Thank You for your Attention

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