The Assessment and Comparison Tool

Status and next steps for the simplified, space-specific, prospective LCA tool

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With the help of the REACT consortium

09/10/2024

Context

Development of the Assessment and Comparison Tool (ACT)

2022 | Green Space Logistics (1y) | REACT (2y) | Nov. 2025

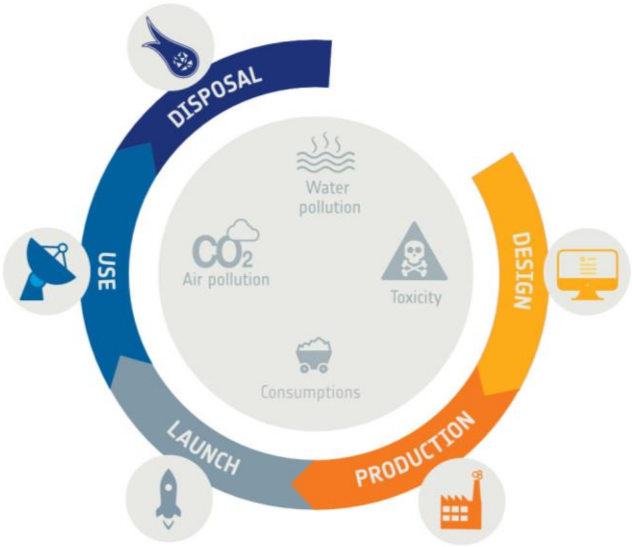
Preparation (9m) | Implementation (15m)

Nov. 2023 | now

"Integrate **environmental** criteria in the **design** process of space transportation **system**"

↳ Space-specific
Simplified
Prospective
Life Cycle Assessment (LCA)

↳ Support ecodesign



https://www.esa.int/ESA_Multimedia/Images/2020/08/EcoDesign_infographic

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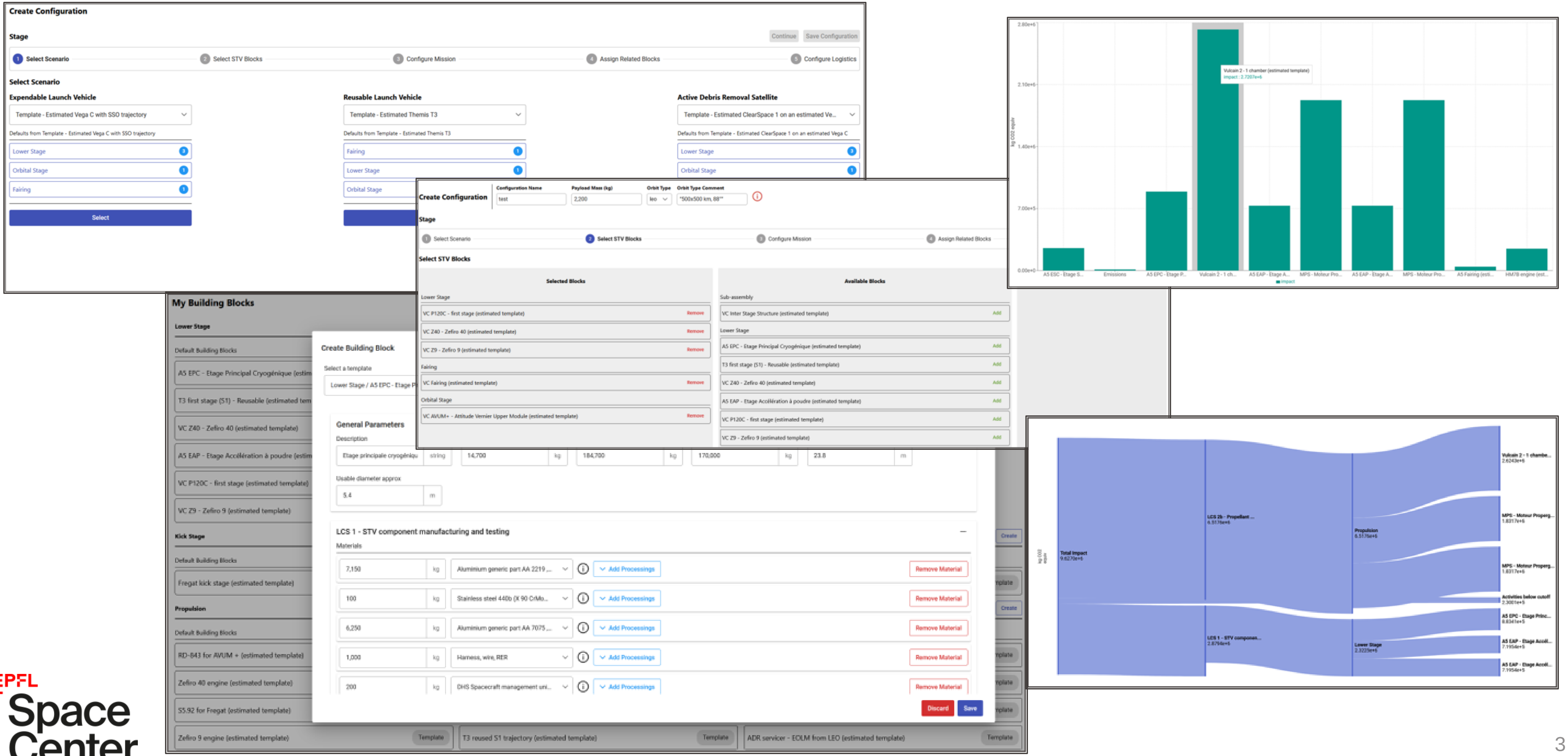
Assessment and Comparison v1



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REACT - Users' needs and motivations

Internal
- Find environmental **hotspots** and key parameters
- **Design** systems with lower environmental impacts ("System-push" or "technology-pull")
- Create a commercial **advantage** / communicate

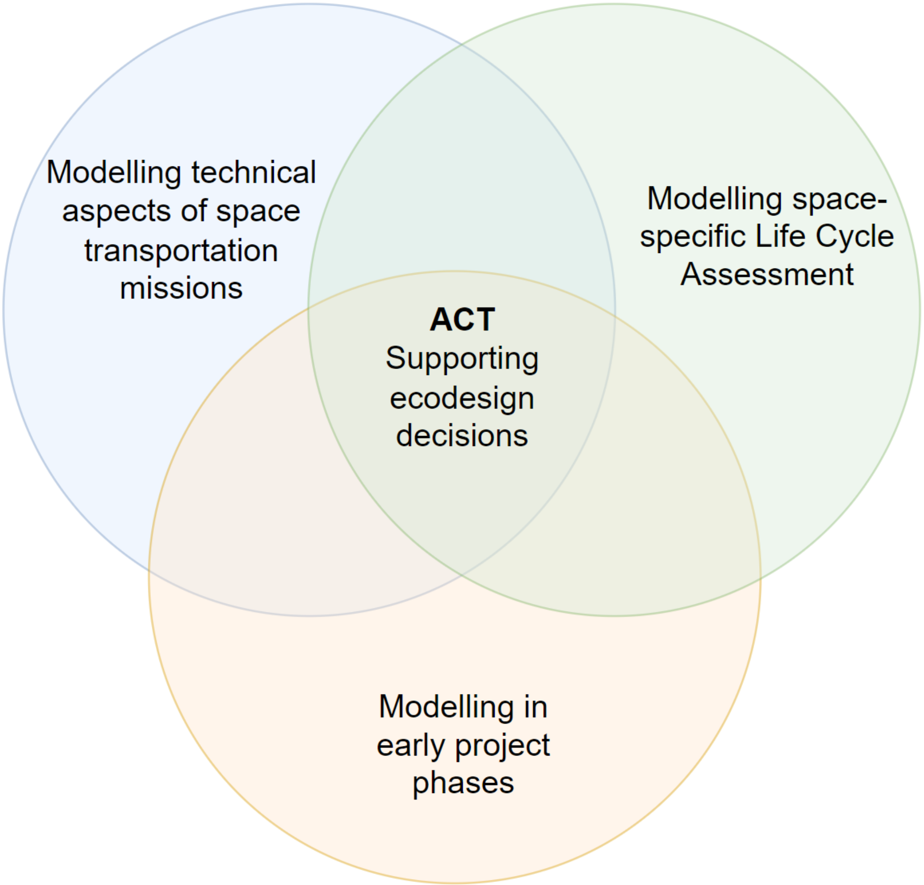
- Lack expertise in environmental assessment (company's **size** and resources)
- Easy adoption thanks to user-friendliness and acceptable learning curve

External (constraints)
- Anticipate / comply to regulatory trends in Europe
- Adapt simplified LCA tools in other sectors
- Fulfil environmental requirements (from agencies)

Courtesy of Ways Ehead

Unique Selling Point

- Understanding users’ requirements
- Internal needs and external constraints
- Describe new features for the v2



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Modelling technical aspects of STVs

ecoinvent

Materials
Components / Equipment

<

Units / subsystems

<

Elements
Systems
Segments

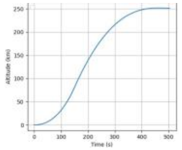
<

Mission

(Custom) LCI datasets

Building blocks

Configurations with ConOps properties and user-defined FU



Sum of configurations (with computed reference flow)

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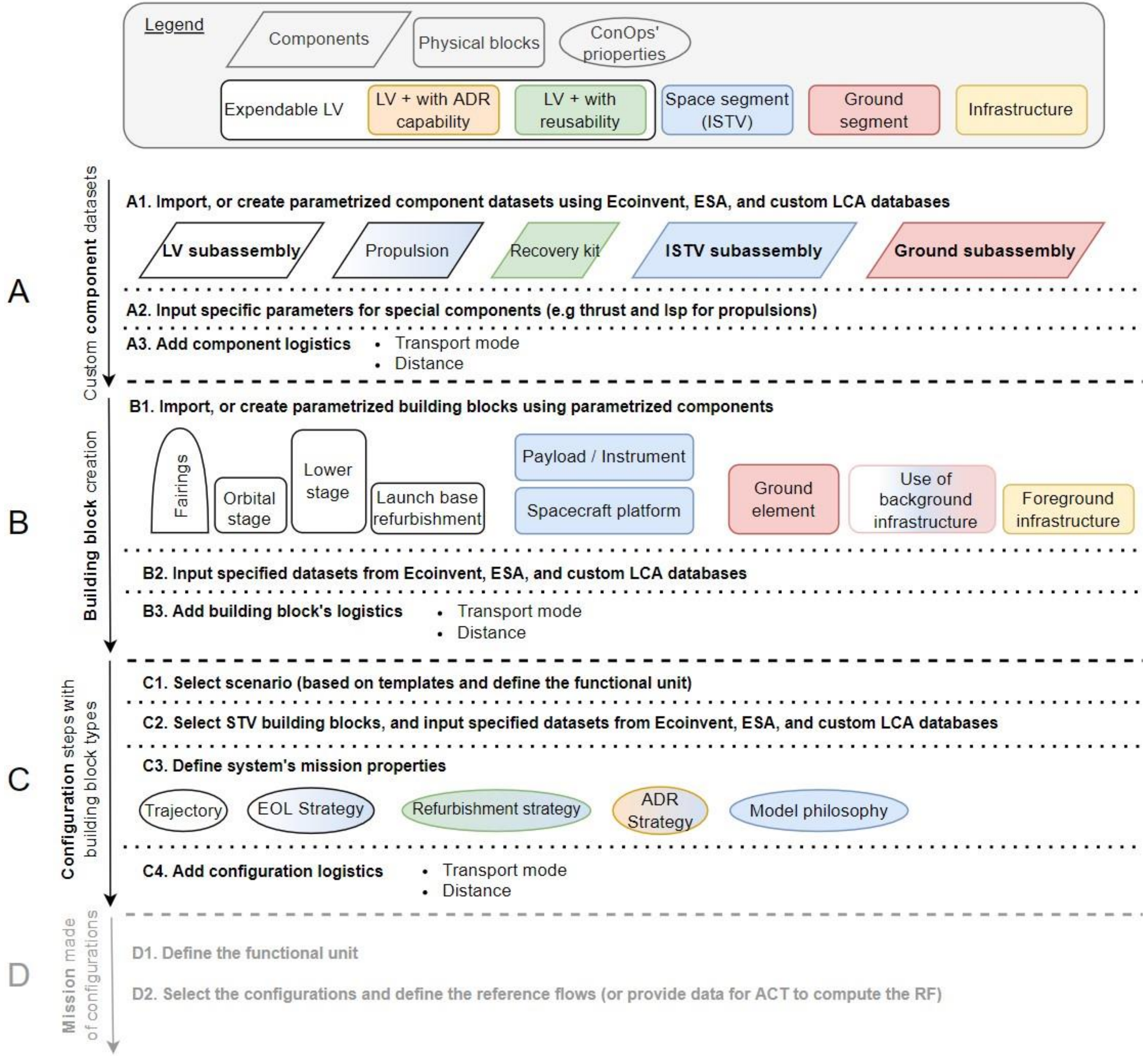

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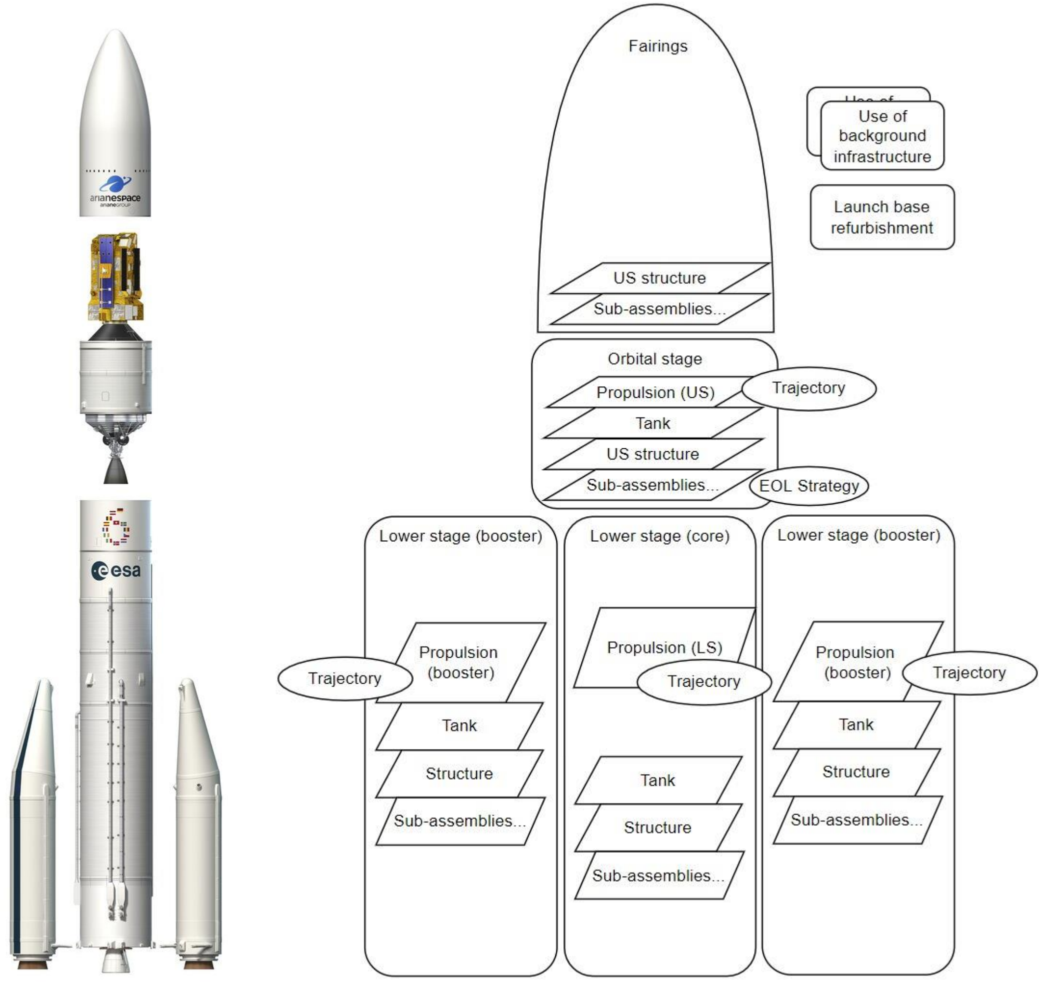
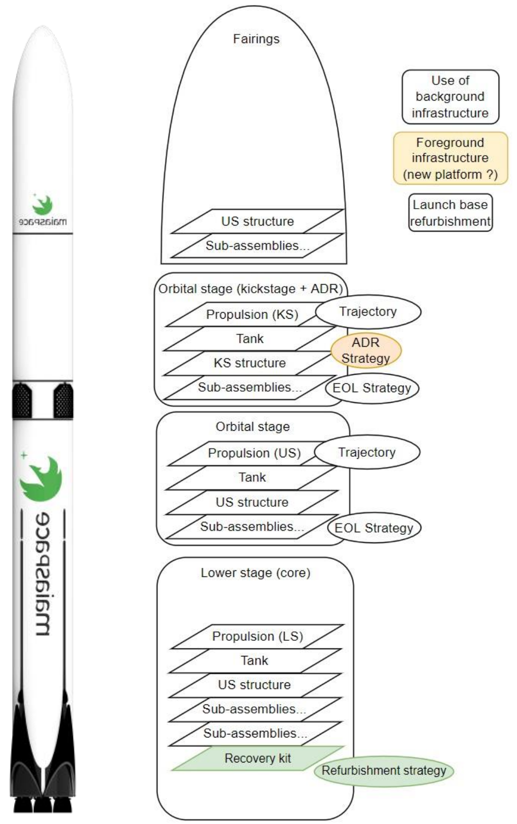
Modelling technical aspects of STVs





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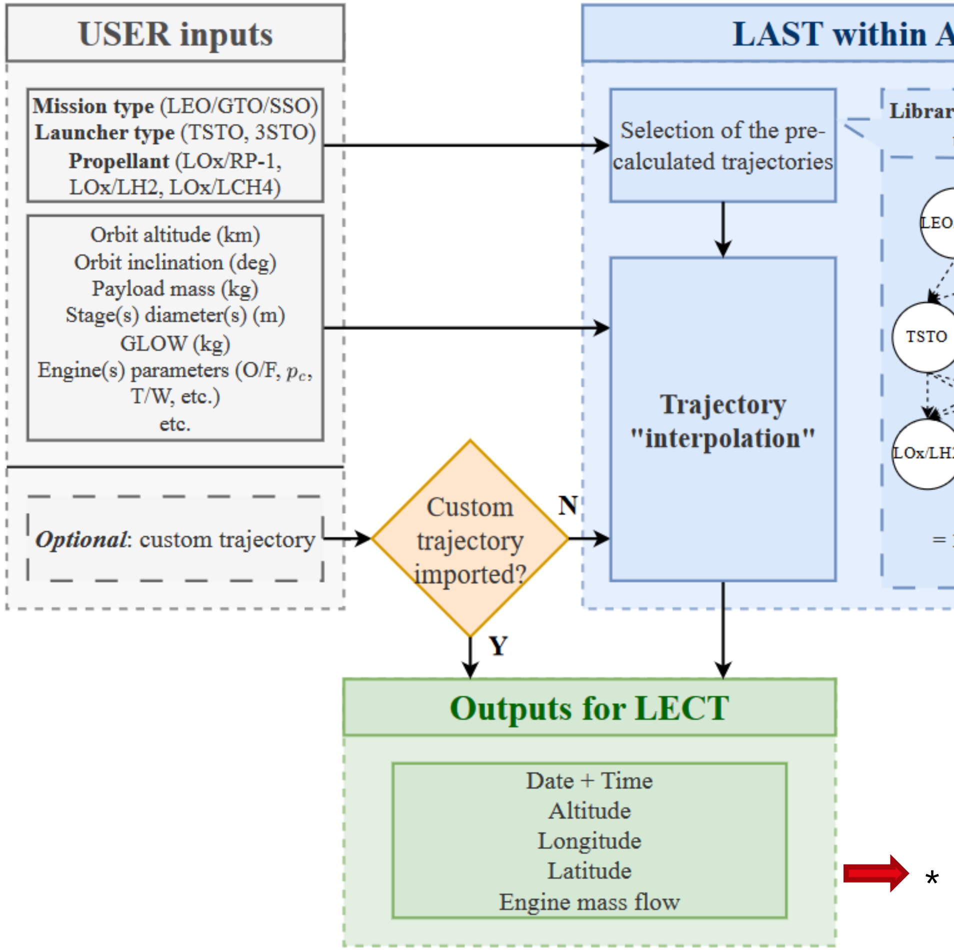
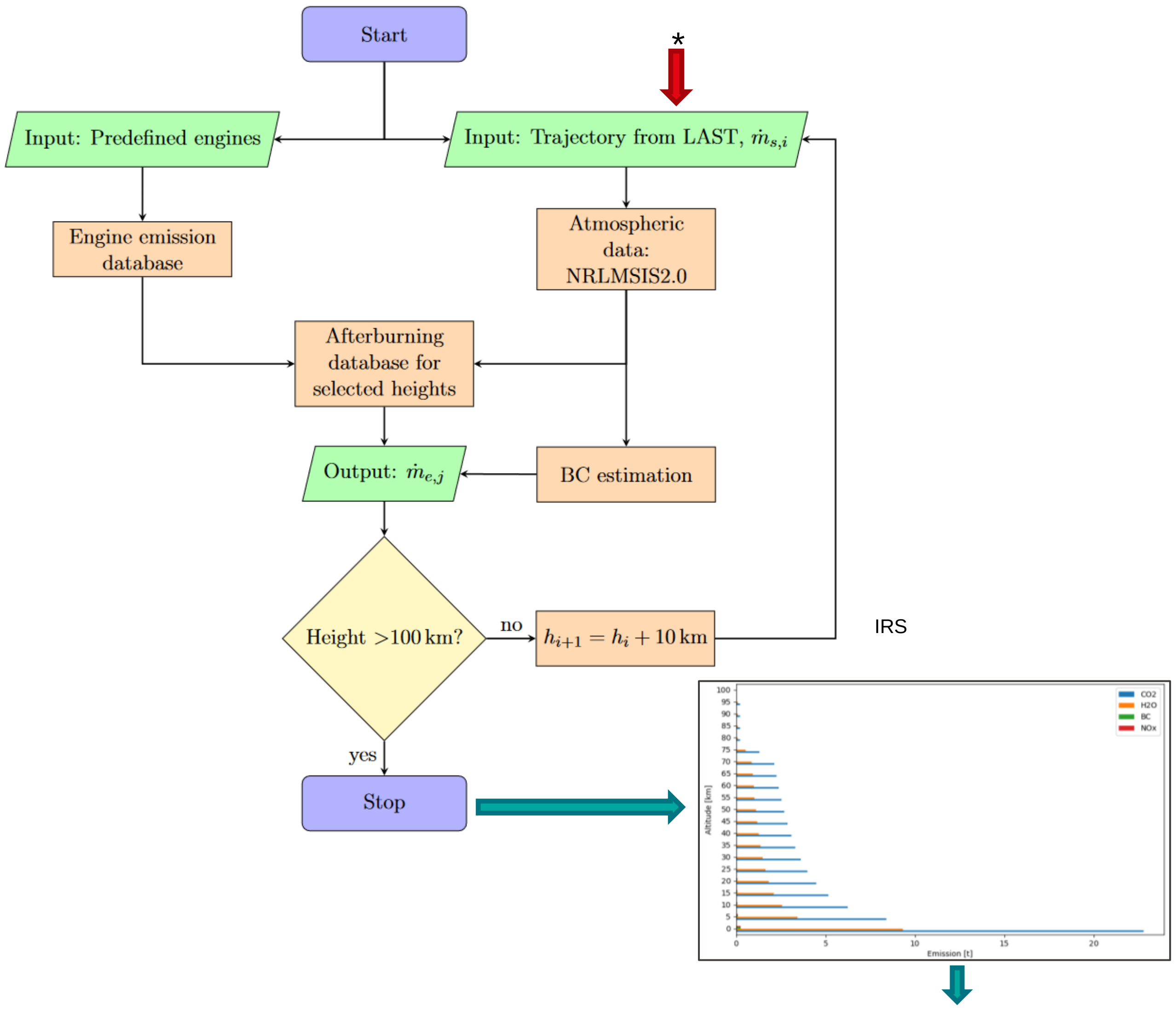
Modelling space-specific LCAs



ISAE



IRS

Emissions Impact Calculation Tool

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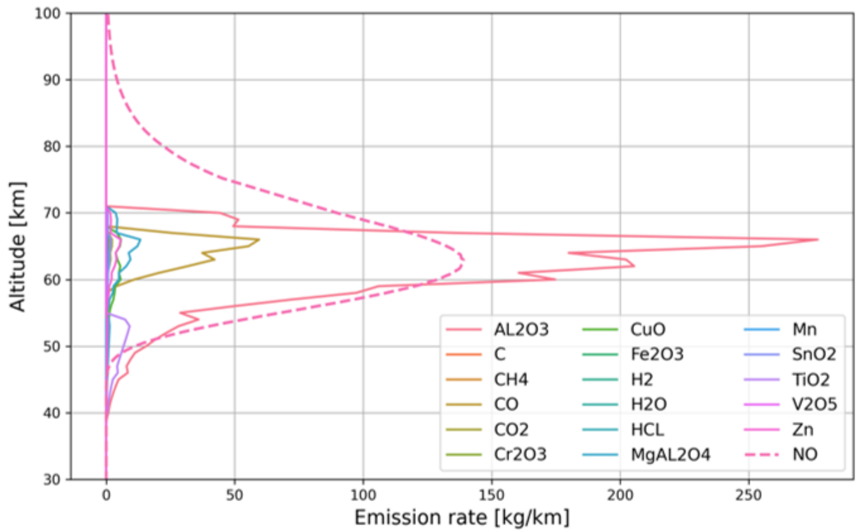
Modelling space-specific LCAs

System and reentry parameters



IRS

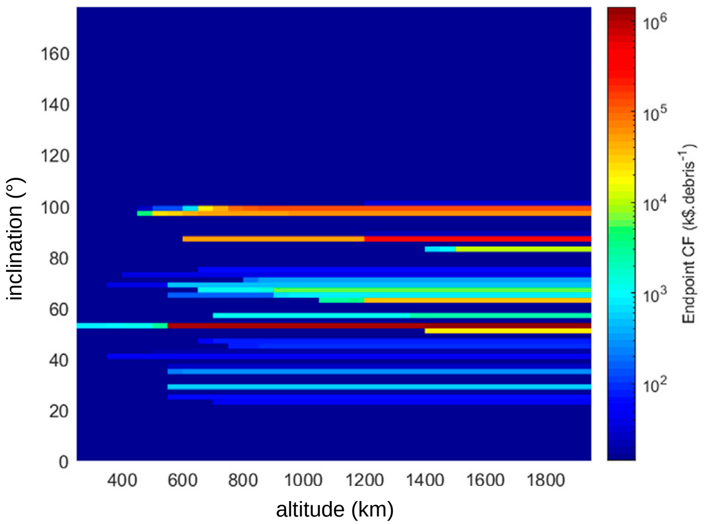
Emissions Impact Calculation Tool

IRS tools, models and uncertainties in more details
→ Jan-Steffen's presentation just after this one…

Materials → Flow indicators with information on **REACH** → ESA REACH tool and Critical Raw Materials (**CRMs**) list

Orbital and end-of-life parameters

Space Debris Index (**SDI**, 2022 version)
Debris risk characterized in terms of economical loss with unit [kilo $]



Maury-Micolier, T., et al. (2022). A new impact assessment model to integrate space debris within the life cycle assessment-based environmental footprint of space systems. *Frontiers in Space Technologies*, *3*. https://doi.org/10.3389/frspt.2022.998064

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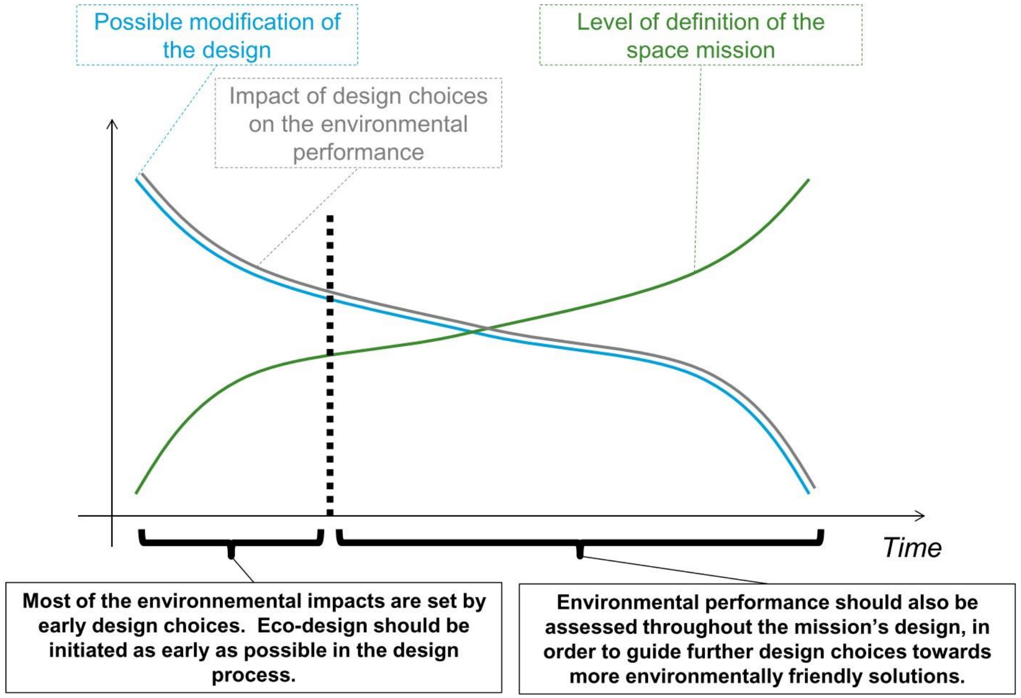
Modelling in early design phases



Augustin Chanoine et al. Integrating sustainability in the design of space activities: development of eco-design tools for space projects. Tech. rep. 145. 2015.

- Ecodesign needs to happen in early design phases
- But data availability is still low
- **Prospective** data is useful (IAMs)
- LCA is often used to support ecodesign
- Comparisons in relative values > absolute values
- Collaboration between technical team and LCA expert
- Engineers shall identify *actionable* ecodesign recommendations (vs number of suppliers?)

→ iterations, data quality rating, sector-specific impacts, etc.

ACT is intended for early phase but user input granularity can evolve along the project !

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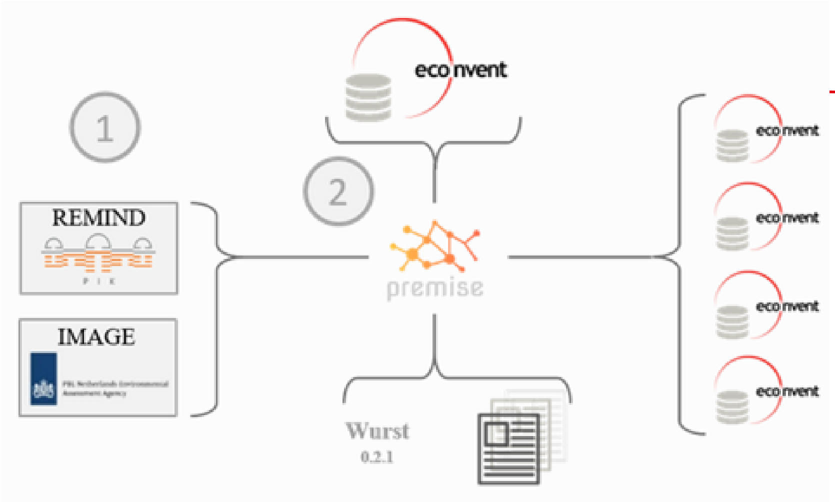
Prospective data

The world will look different in future. Integrated Assessment Models (IAMs) **model scenarios**, e.g. for IPCC with regards to mean global temperature rise and related policies.
Premise couples the IAM with ecoinvent and the ESA database (**background**).

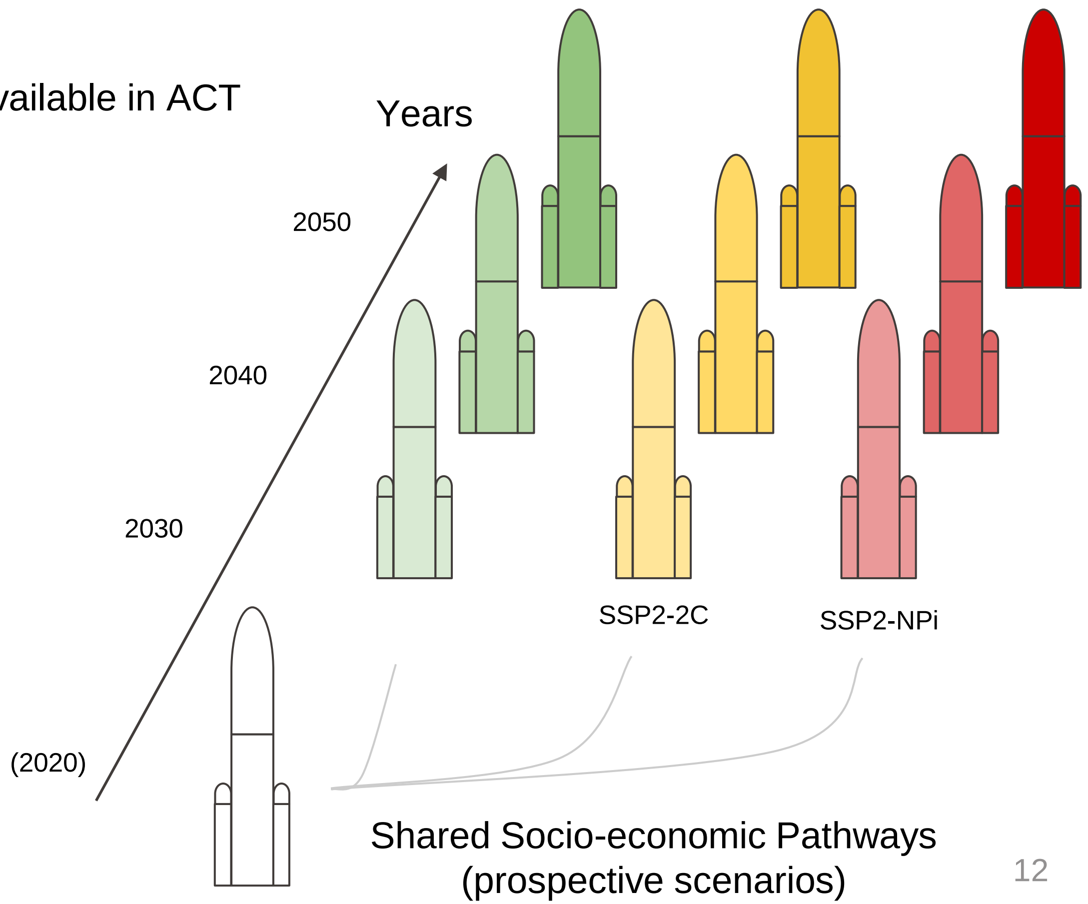


Current, 2030, 2040, 2050

3 model scenarios

10 DBs ➡ Available in ACT

Sacchi, R., et al. (2022). PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models. *Renewable and Sustainable Energy Reviews*, *160* (April 2021), 112311. https://doi.org/10.1016/j.rser.2022.112311



Possible comparisons

A) One configuration in several years and scenario →
B) Different configurations (same FU) in the same year and scenario

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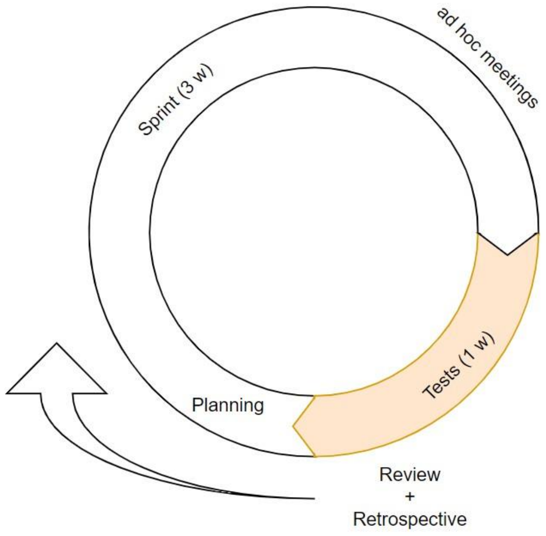
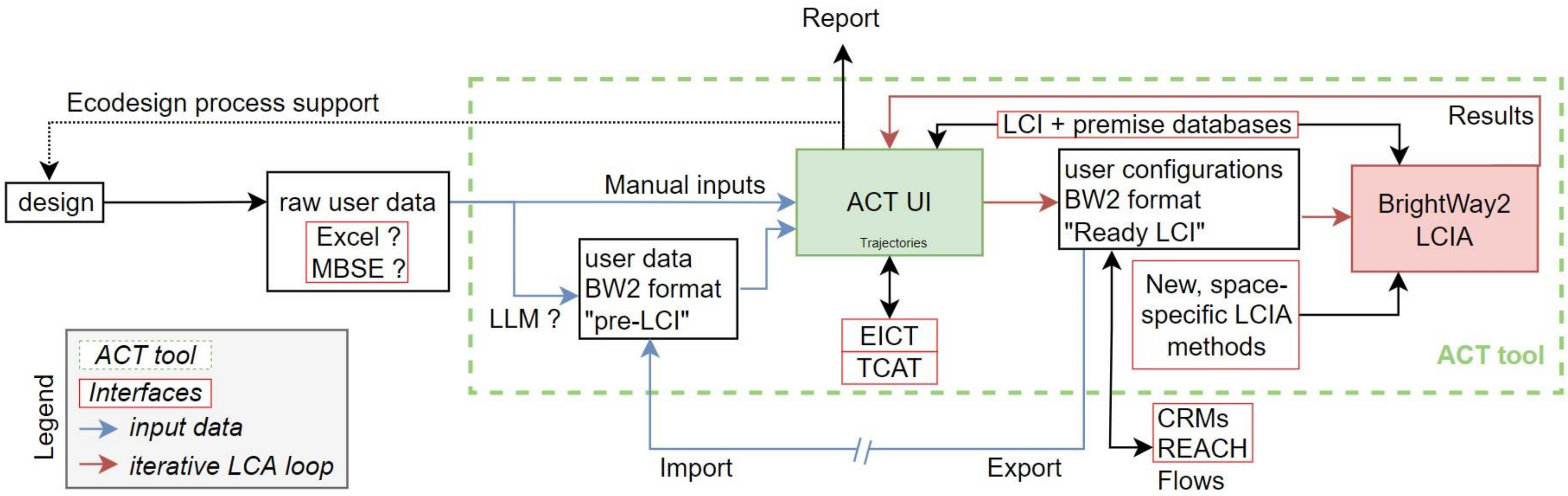
Next steps



- Iteratively develop and test features
- Stay up to date with state-of-the-art and regulations
- Test intermediate tool release with ESA and companies
- Write documentation
- Investigate connections with emerging technologies



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Use case with ACT proof of concept

Successfully used (with known limitations) in the context of early design assessments
→ see more **tomorrow 9:30am** (auditorium Erasmus)

Screening life cycle assessment of families of future reusable launchers for early-stage ecodesign considerations in the VOLARE project

With Blandine Quelennec (ArianeGroup)

CLEAN SPACE

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Conclusion and info

The Assessment and Comparison Tool enables

- Simplified, space-specific and prospective LCA
- Which lowers some obstacles
- From early phase to support ecodesign

- Knowledge, data, and methodological gaps have been identified
  → Announcement of Opportunity can be shared

- More tests are planned → contact us if interested (mathieu.udriot@epfl.ch)

- IAC paper "Modelling technical and environmental aspects for early phases ecodesign decision support" in session D2.9-D6.2 (18.10 at 3:15pm)

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Announcement of Opportunity

Image from blogs.esa.int/cleanspace/

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September 13, 2024

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Thank you, any questions?

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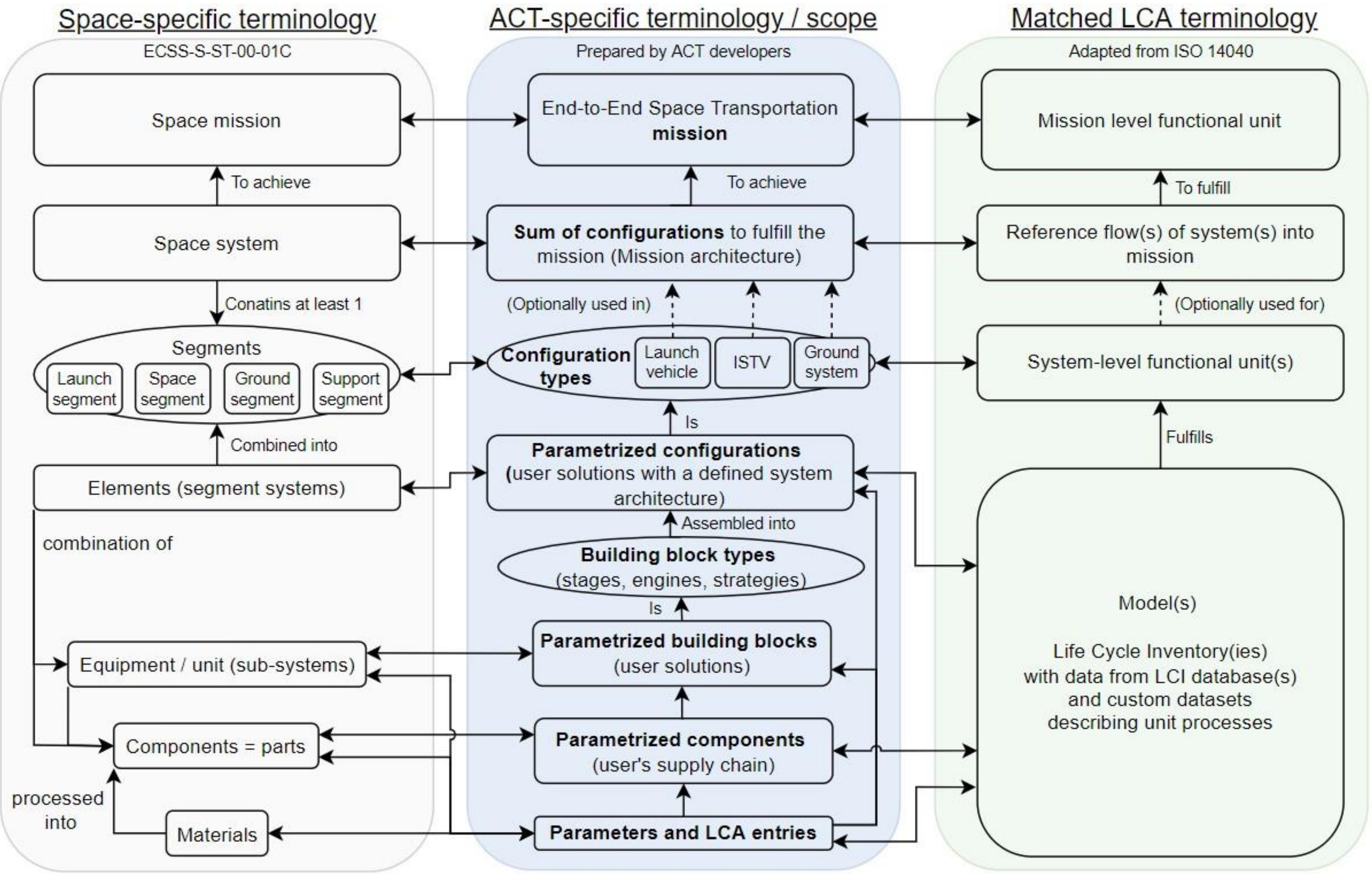
Backup



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LCA simplification approaches

Simplification approach *	ESA LCA handbook (2016)	ACT v2
1. Partly or fully ignoring upstream and/or downstream processes	LCAs are cradle-to-gate for level 2 LCAs. Space mission boundaries include space, launch, and ground segments, and all project phases from A to F. Some exclusions are possible.	Only end-to-end mission can be modeled (level 1 LCA), covering phases A to F, and the three segments. Exclusions can be tracked.
2. Narrowing the range of environmental impacts considered	20 environmental impact indicators are considered (including 5 flow indicators, see below).	Latest version of Product Environmental Footprint (PEF) [21], (currently v3.1 with 25 impact categories). A subset of LCIA indicators is proposed to facilitate the interpretation: Global warming potential, Ozone Depletion Potential, Abiotic Resources Depletion Potential, Cumulative Energy Demand, Human toxicity, Ecotoxicity.
3. Mixing qualitative and quantitative data	Some flow indicators (Primary Energy Consumption Potential (MJ), Gross Water Consumption Potential (m^3), mass left in space / in the ocean, mass of Al_2O_3 emissions).	Flow indicators including launch and reentry emissions (see section 5.2), and qualitative data quality assessment.
4. Using surrogate process data (proxies).	Some proxy examples are provided	Can be done by selecting proxy datasets from the databases.
5. Establishing showstopper criteria	Not mentioned, the model must fulfill the functional unit.	Only checking the validity of some user inputs. Technical feasibility of the system is under the responsibility of the users.
6. Limiting the constituents studied to those meeting a threshold volume	Yes, with conditions for mass cut-off criteria that it's less than 5\% of the total mass, not listed under REACH “Authorisation List” or as a critical raw materials (CRM), or there is "no particularly high environmental or health risk“ [20].	Yes, the granularity (level of detail with more or less datasets) of the model is decided by users.
7. Cut-off	Idem as 6.	Idem as 6.
8. Tool/database	The ESA database which is built on top of the ecoinvent database, and provides space-specific datasets to practitioners.	The ecoinvent and ESA database are available, custom databases can be imported too. ACT also support the LCIA and interpretation steps.
9. Comparative LCA with the omission of identical elements	Not directly mentioned, omissions must be reported.	Voluntary exclusions can be listed in a table to be tracked in the report.
10. Screening	Not mentioned.	It's the purpose of the tool: to highlight the hotspots as early as possible during the design phase.

* Based on Katja Tasala Gradin and Anna Björklund. The common understanding of simplification approaches in published LCA studies - a review and mapping. Jan. 2021. DOI: 10.1007/s11367-020-01843-4.

To be published. Udriot, M., et al. (2024). Sustainability of End-to-End Space Transportation Missions: Modelling Technical and Environmental Aspects for Early Phases Ecodesign Decision Support. *75th International Astronautical Congress 2024*.

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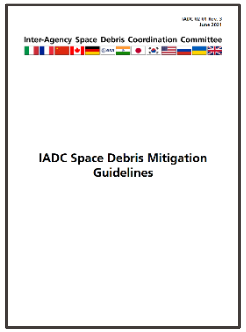
Comparison with other methods

Comparison with other methods:

- LCA vs simplified LCA
- Different applications
- Criteria to choose the method

Examples:



Methods	User entry barrier (-)	Data requirements (-)	Study scope (+)	Reliability of results (+)	Ease to apply during design (+)
LCA	3	3	3	3	1
Simplified LCA	2	2	2-3	2-3	2*
Mono-criteria approaches	2	2	2	2	1
Matrices	1	2	2	1	2
Checklists	1	1	1-2	1	2
Guidelines	1	2	1-2	N/A	2-3
Lists of substances	2	3	2	2	2

* ACT aims to facilitate it.

To be published. Udriot, M., et al. (2024). Sustainability of End-to-End Space Transportation Missions: Modelling Technical and Environmental Aspects for Early Phases Ecodesign Decision Support. *75th International Astronautical Congress 2024*.

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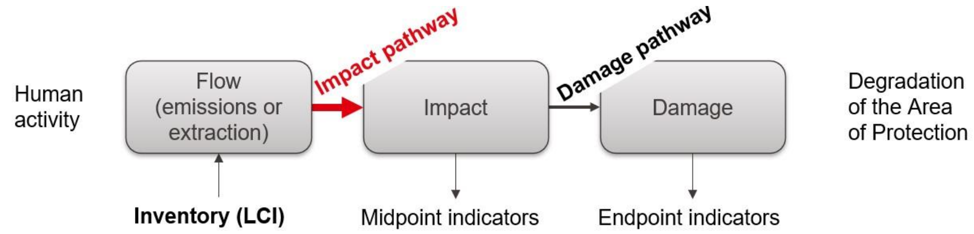
Impact indicators



Environmental Indicators	Unit	ESA Handbook v1	ESA Update	PEF	SSSD	ACT v1	ACT v2
		Methodology					
Climate Change							
Global Warming Potential (100 y)	kg CO2 eq.	IPCC 2007	IPCC2013	IPCC2013	IPCC 2013	IPCC 2021	IPCC 2021
Stratospheric Ozone Depletion							
Ozone Depletion potential	kg CFC-11 eq.	WMO 1999	WMO 2014 + integrations	WMO 2014 + integrations	CML 2001 / WMO 1999	WMO 2014 + integrations	WMO 2014 + integrations
Human Health							
Human toxicity potential, cancer	CTUh	USEtox	USEtox 2.1	USEtox 2.1	USEtox		USEtox 2.1
Human toxicity potential, non-cancer	CTUh	USEtox	USEtox 2.1	USEtox 2.1	USEtox		USEtox 2.1
Resource depletion							
Abiotic resource depletion potential (metal and mineral resources)	kg Sb eq.		CML 2002 (ultimate reserve)	CML 2002	CML 2001	CML 2002 (ultimate reserve)	CML 2002 (ultimate reserve)
Abiotic resource depletion potential (fossil and mineral resources)	kg SB eq.	CML2002 (reserve base)					
Abiotic resource depletion potential (fossil fuels)	MJ	CML2002	CML 2002	CML 2002	CML 2001		CML 2002
Metal depletion potential	kg Fe eq.	ReCiPE H					
Land system change							
Land use	pt		LANCA	LANCA			LANCA
Freshwater Use (PB)							
Gross Water Consumption Potential	m3	ESA LCA 2016					
Water use	m3 world eq.		AWARE	AWARE			AWARE
Water Consumption - Water Depletion Potential	m3 water ew. of deprived water				ReCiPe Midpoint (H)		
Energy consumption							
Primary Energy Consumption Potential	MJ	ESA LCA 2016	ESA LCA 2020				ESA LCA 2020
Energy Consumption					Cumulative Energy Demand	Ecoinvent, CED HHV non-renewable	
Biochemical Flows							
Freshwater eutrophication potential	kg P eq.	ReCiPE H	ReCiPe	ReCiPe	ReCiPe Midpoint (H)		ReCiPe
Marine eutrophication potential	kg N eq.	ReCiPE H	ReCiPe	ReCiPe	ReCiPe Midpoint (H)		ReCiPe
Terrestrial Eutrophication potencial	kg N eq.		Accumulated Exceedance	Accumulated Exceedance			Accumulated Exceedance

Environmental Indicators	Unit	ESA Handbook v1	ESA Update	PEF	SSSD	ACT v1	ACT v2
		Methodology					
Atmospheric Aerosol Loading							
Particulate matter formation potential	kg PM10 eq/Disease incidence	ReCiPE H	PM UNEP 2016	PM UNEP 2016	ReCiPe Midpoint (H)		PM UNEP 2016
Soot (black carbon) emissions	kg		ESA LCA 2016			GSL 2023	REACT 2025
Ecotoxines							
Freshwater ecotoxicity potential	CTUe/PAF.m3.day	USEtox	USEtox 2.1	USEtox 2.1	USEtox		USEtox 2.1
Marine ecotoxicity potential	kg 1,4-DB eq.	CML 2002	CML 2002		CML 2001		CML 2002
Atmospheric Impact							
Photochemical ozone formation potential	kg NMVOC eq.	ReCiPE H	ReCiPe 2008	ReCiPe 2008	ReCiPe Midpoint (H)		ReCiPe 2008
Ionising Radiation Potential	kBq U 235 eq./kg U235 eq	ReCiPE H	Frischknecht et al., 2000	Dreicer et al. 1995	ReCiPe Midpoint (H)		Frischknecht et al., 2000
Air acidification potential	mol H+ eq.		Accumulated Exceedance	Accumulated Exceedance			Accumulated Exceedance
Air acidification potential	kg SO2 eq.	CML2002	CML 2002		CML 2001		CML 2002
Al2O3 particle emissions	kg	ESA LCA 2016	ESA LCA 2016		ESA (2016)	GSL 2023	REACT 2025
Re-entry Smoke Particles - RSP Creation Potential	kg RSP eq				SSSD 2019		REACT 2025
Space Debris							
Mass left in space flow indicator	kg	ESA LCA 2016	ESA LCA 2016				
Orbital Risk - Space Debris Risk	Index Score				Politecnico di Milano et al (2017) / SSSD 2019	T. Maury et al., Space Debris Index (2019)	T. Maury et al., Space Debris Index (2019 + 2022)
Orbital Space Use - Orbital Resource Depletion Potential	objects.m3.year				University of Bordeaux et al (2018)		
Mass disposed in ocean flow indicator	kg mass	ESA LCA 2016	ESA LCA 2016		ESA (2016)		
Policies							
Critical Raw Materials - CRM Use Potential	kg mass				SSSD 2019		REACT 2025
REACH Substances - Restricted & SVHC Use Potential	kg mass				SSSD 2019		REACT 2025
Economic							
Economic Impact - Single Score	EUR 2000				SSSD 2019		
Noise							
Noise Pollution - Noise Creation Potential	Av Leq / Cat				SSSD 2019		
Social							
Social Impact - Single Score	Social Score				SSSD 2019		

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