EPFL's first steps toward the Eco-Design of the CleanSpace One mission

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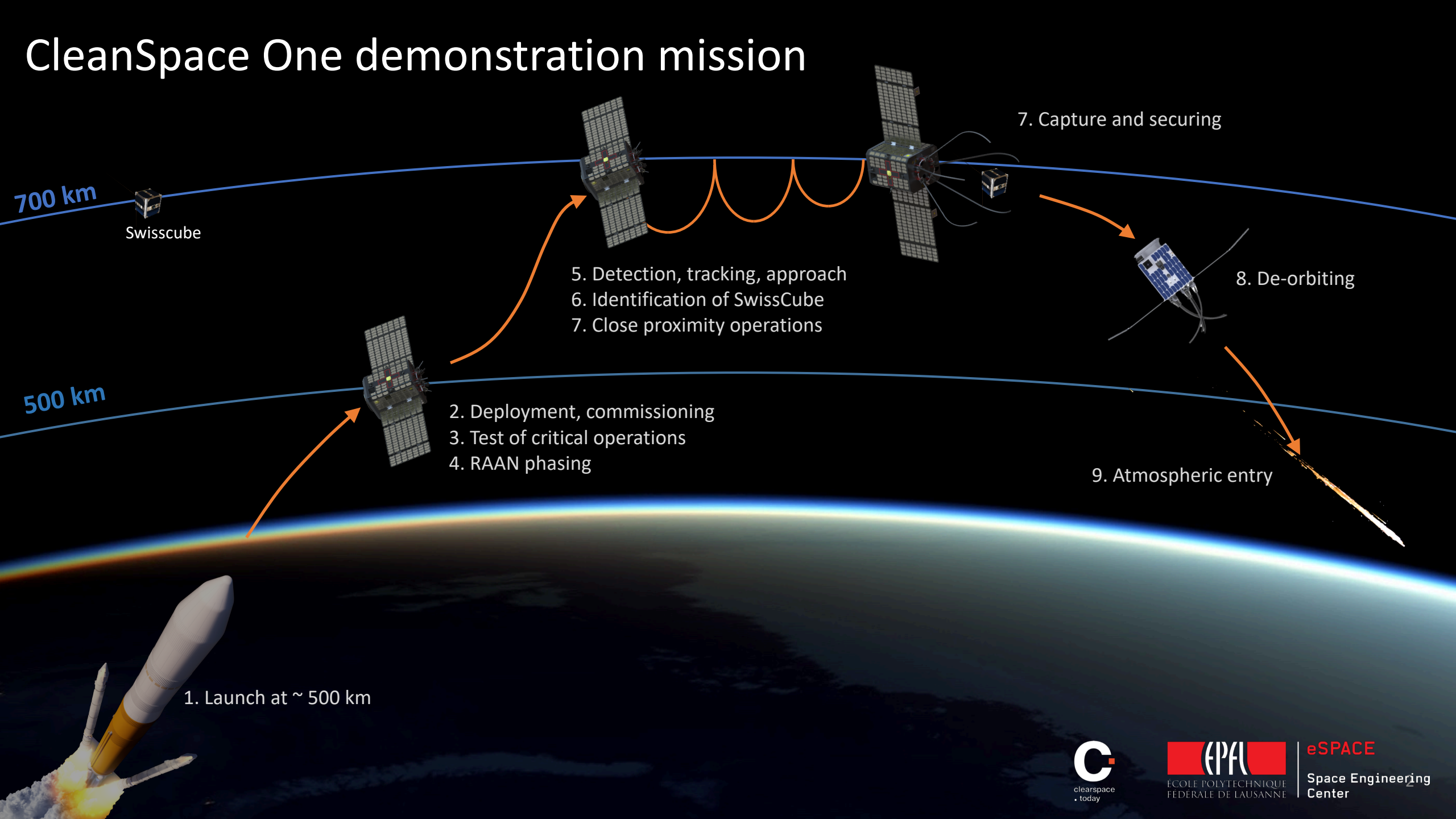
AIUB

Hes·so
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences and Arts Western Switzerland

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

CleanSpace One demonstration mission



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Why an LCA for CSO?

- Consistent with the project's intentions
- Help design choices: technology/components trade-offs, or design that reduces the environmental impact
- Investigate integration into the project's MBSE model
  - The integration of a LCA tool in the MBSE environment would allow to consider the environmental performance of a mission as an optimisation parameter, at the same level as the weight or cost optimisation.
- The work presented here is the result of a student semester project (equivalent to a total of 3 weeks of work, including ramp-up and report)

First step:

esa

DOCUMENT

Space system Life Cycle Assessment (LCA) guidelines

Prepared by	ESA LCA Working Group
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Issue	1
Revision	0
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European Space Agency
Agence spatiale européenne

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Ecodesign: From previous LCA

- Launch phase is the biggest contributor: stage production contributes to 30% of most impacts: Importance of reusable rockets !

- Launch phase: 15% of GWP transport of the rocket to Kourou: Importance of production close to launch area

- Office work (electricity and infrastructure): important role for the whole mission, especially for C-D phase. Same as many industries: sustainable energy is required.

Model Based System Engineering

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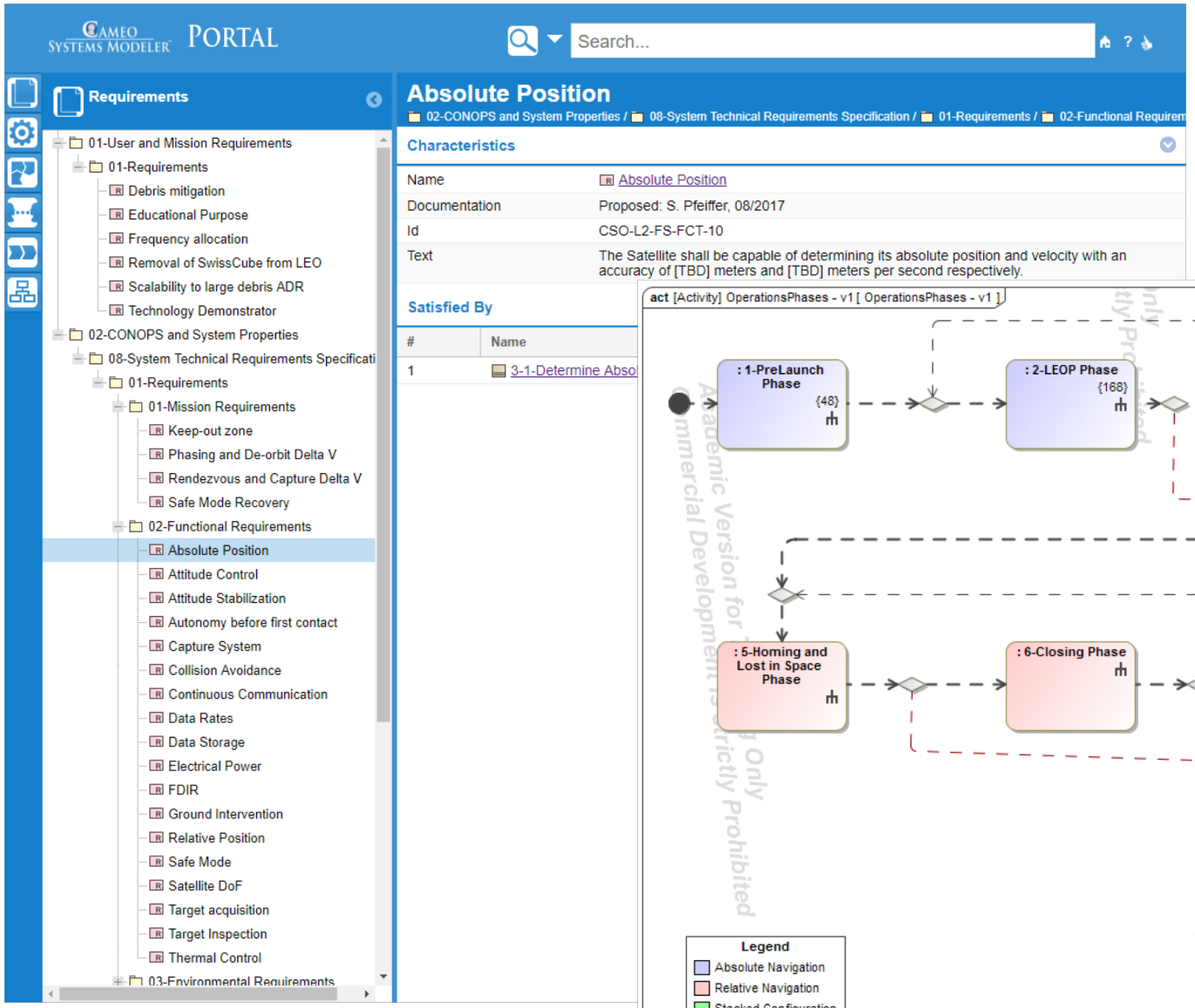
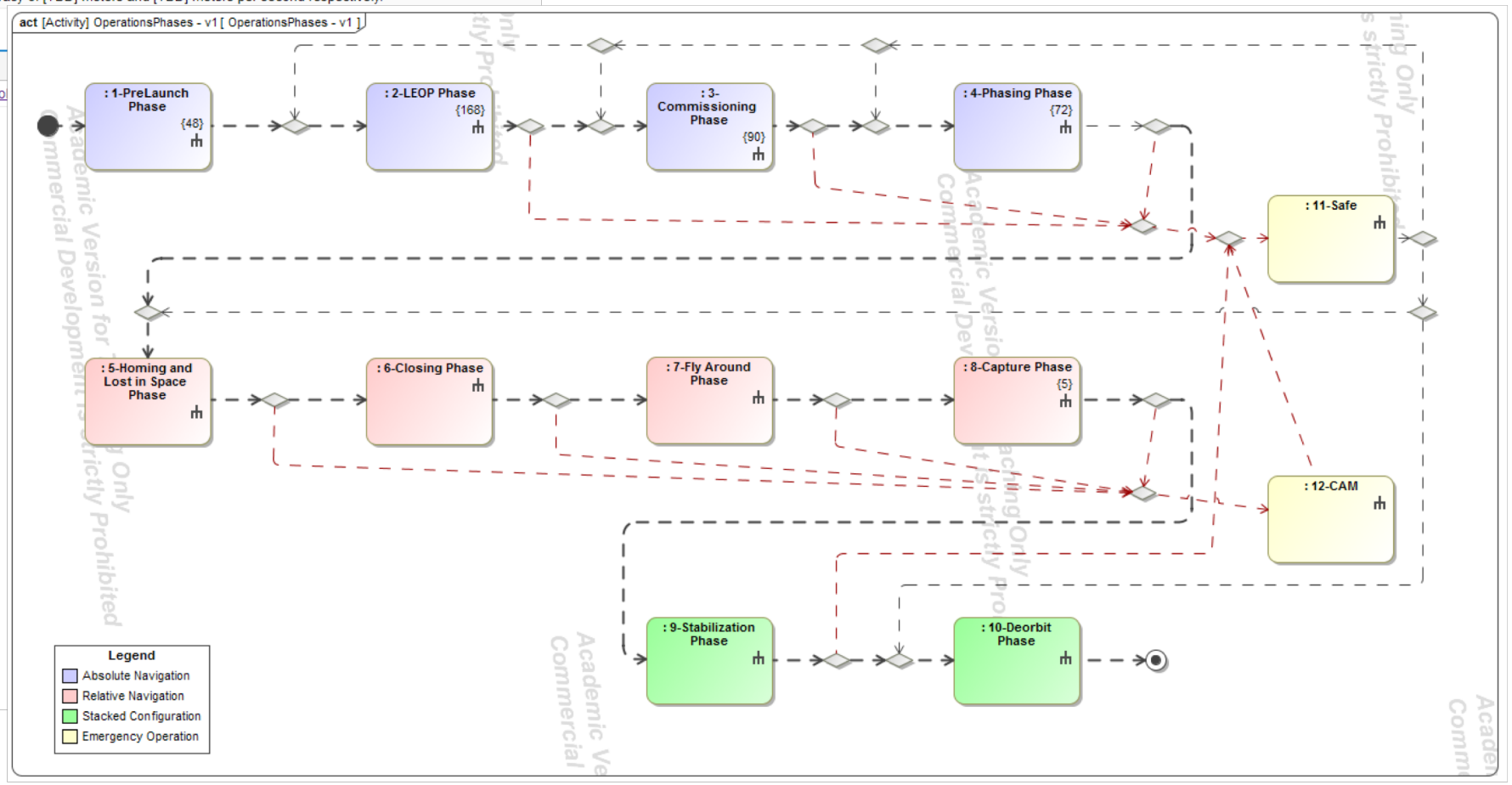
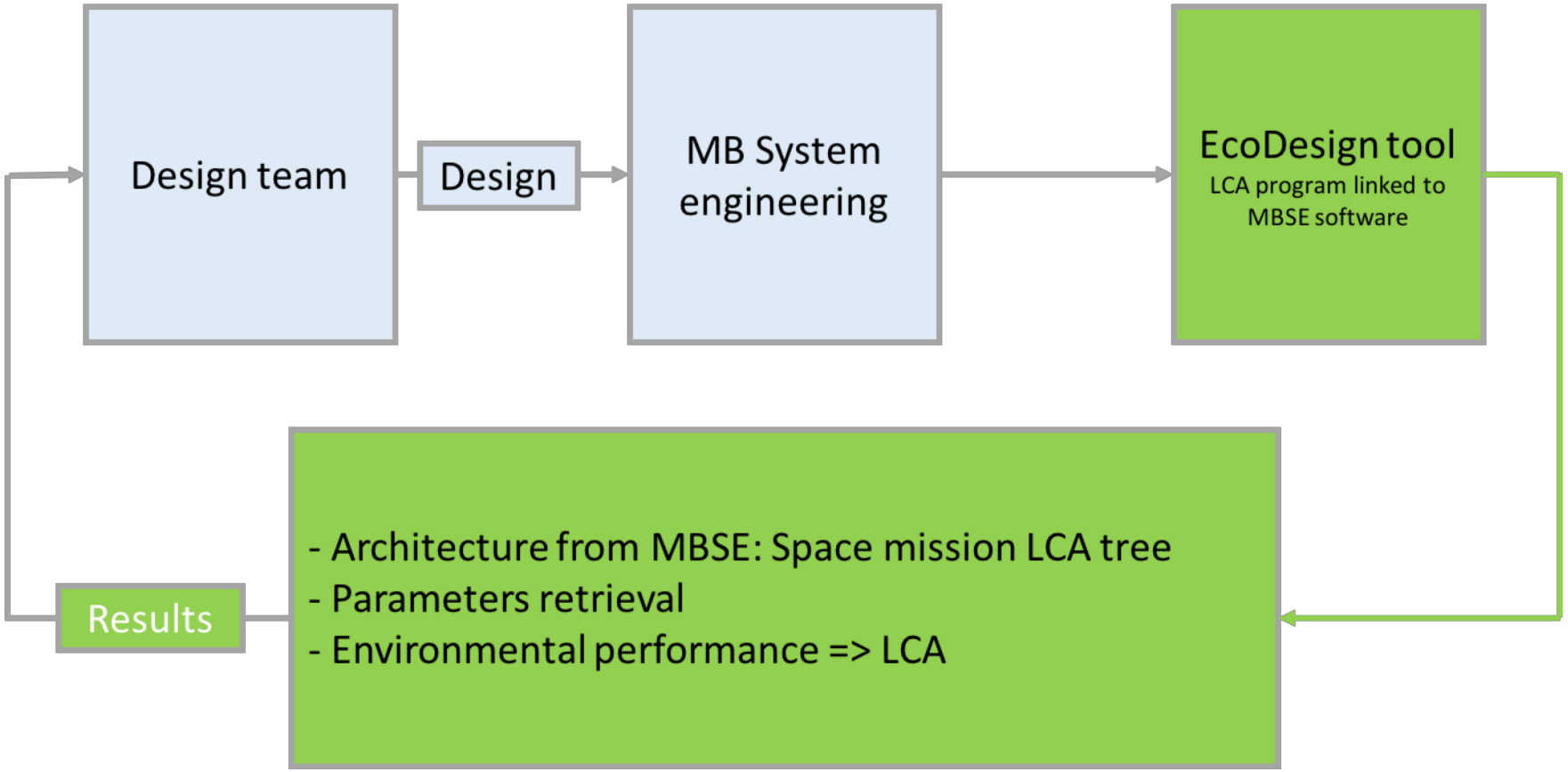
- Model of CSO system and states





Ecodesign: LCA of CSO

- Include LCA in MBSE



- Link project/system description (timeline, hardware…) link to LCA Excel node

LCA into CAMEO

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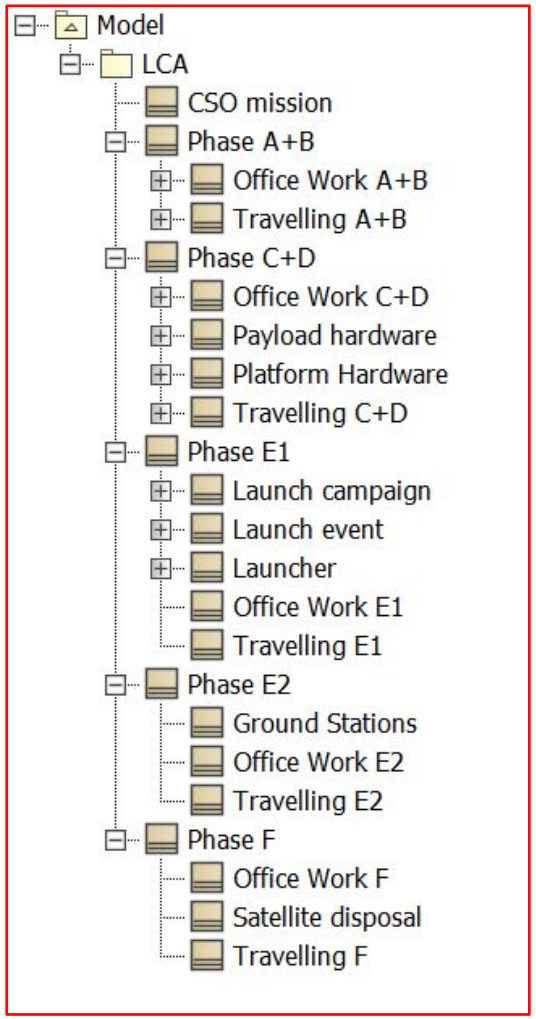
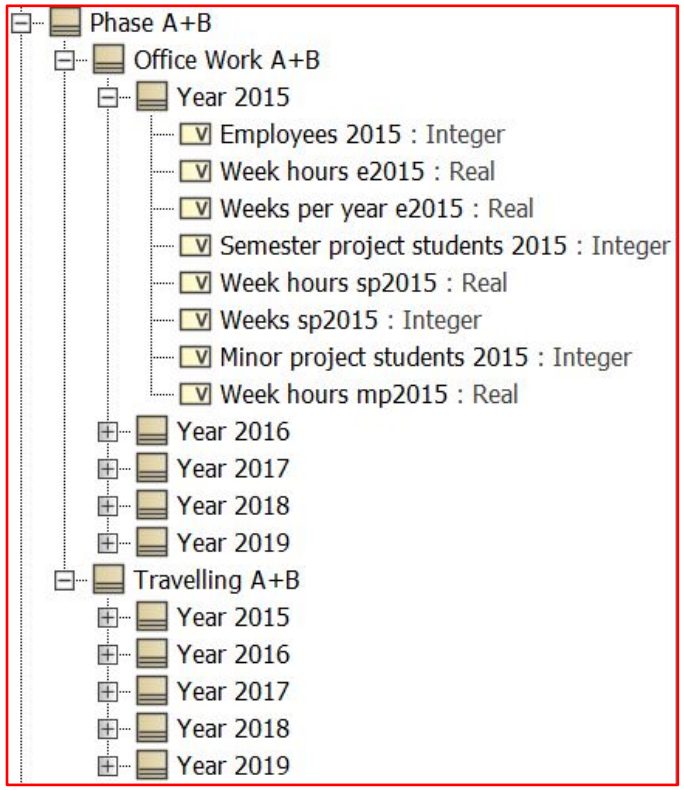
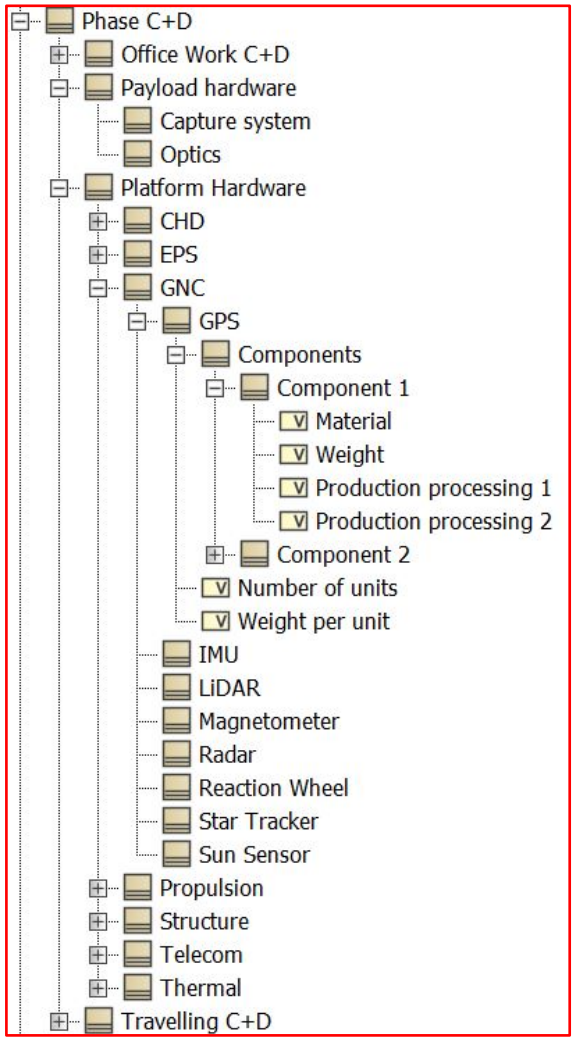
Whole model



Phase A+B

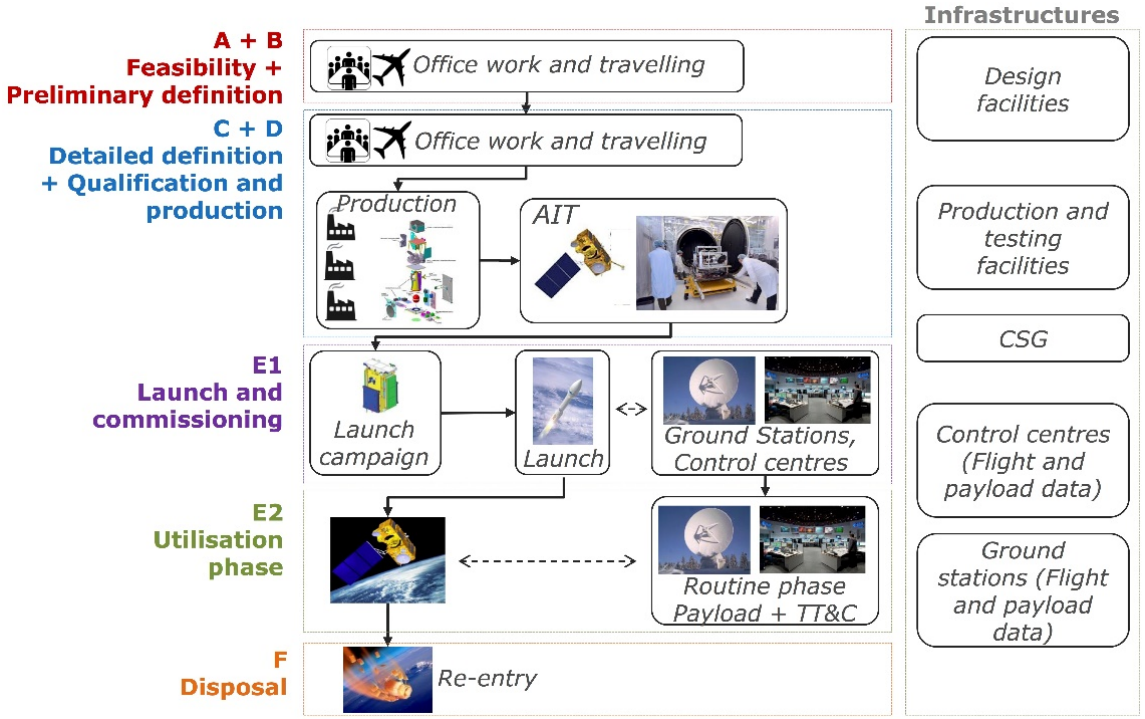


Phase C+D



LCA of CSO: Excel model

System boundaries and mission breakdown:



Mission phases
1. Office Work
2. Transport
3. System
   1. Year
   2. Year
   3. Subsystem
      1. Flows
      2. Flows
      3. Components
         1. -
         2. -
         3. Subcomponents
            1. -
            2. -
            3. Flows

LCA of CSO: Excel file structure

- Phase 0+A+B, Phase C+D, Phase E1, Phase E2, Phase F
- Transport: contains several flows for the transport.
- Infrastructure: contains one flow for EPFL buildings.
- Electricity: contains several flows for electricity.

- Databases:
  - EcoInvent 2.2
  - EPFL Sustainable Campus

LCA of CSO: Excel model

- Inputs

Office Work	Year 2016	Year 2017	Year 2018	Year 2019	Year 2020
Employees	5	5	5	15	15
Work Hours per week per employee	45	45	45	45	45
Weeks per employee per year	46	46	46	46	46
Semester project students	10	10	19	10	10
Work Hours per week per student	15	15	15	15	15
Weeks of work per student	16	16	16	16	16
Minor project students	5	5	5	5	5
Work Hours per week per student	18	18	18	18	18
Weeks of work per student	16	16	16	16	16
Commuting					
Distance by Scooter [km]	0	0	0	0	0
Distance by Car [km]	8718	8718	8718	8718	8718
Distance by Public transport [km]	14706,3	14706,3	14706,3	14706,3	14706,3
Travelling					
Distance by Plane (Europe) [km]	36000	36000	36000	36000	36000
Distance by Plane (intercont.) [km]	0	0	0	0	0
Distance by Train (CH) [km]	0	0	0	0	0
Distance by Train (EU) [km]	0	0	0	0	0
Distance by Car [km]	0	0	0	0	0

Assumptions	Factor 1		Factor 2		Factor 3	
Plane	3000	km/month	(GE-Amsterdam 700km)			
Car	1.6/1.14	passenger/car	0,34	Employees (car)	0,0355	Students (car)
Students	100	km/week	16	weeks/semester		
Employees	100	km/week	46	weeks/year		
Train	6	km Flon-EPFL	60	km/week		
Students	0,625	Students (tp)				
Employees	0,4135	Employees (tp)				
PPH building	3240	m^2	80	ans (durée vie)	3	m (hauteur étage)
EPFL building area 2016	429223	m^2				
EPFL electricity consumed 2016	70779	MWh				
EPFL specific electricity per building	0,164900297	MWh/m^2				
	164,9002966	kWh/m^2				
MWh to MJ	3600					

LCA of CSO: Excel model

- Outputs

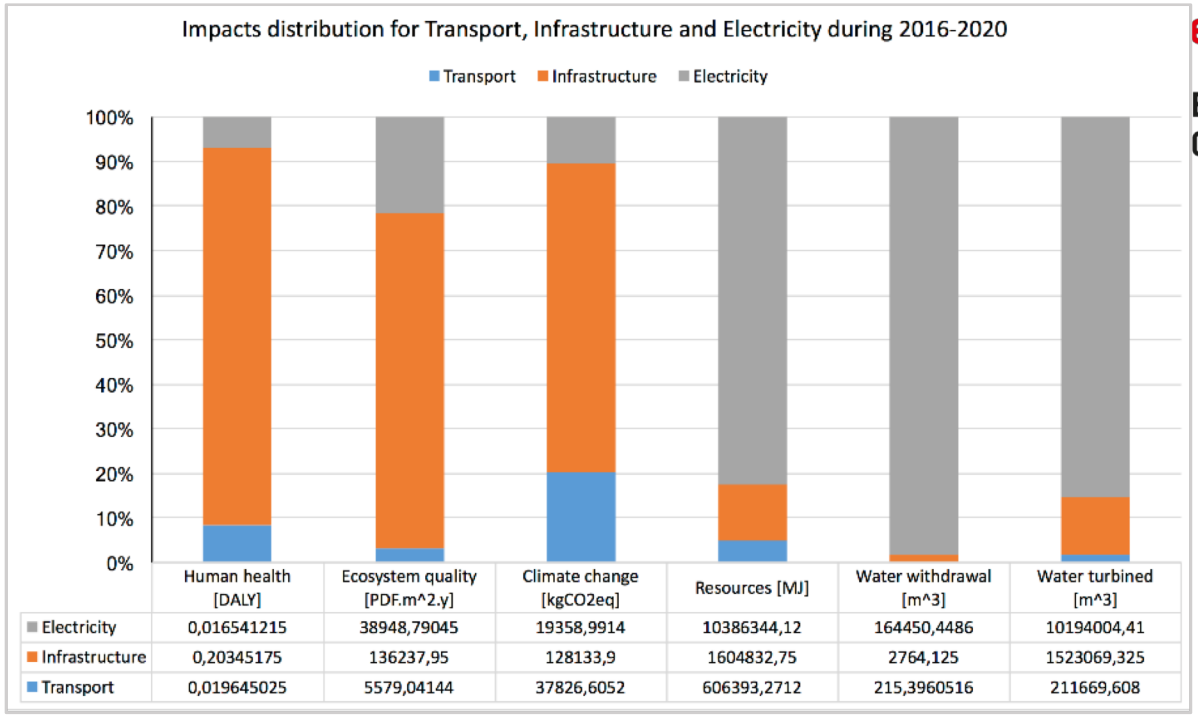
		Human health [DALY]	Ecosystem quality [PDF.m	Climate change [kgCO2eq]	Resources [MJ]	Water withdrawal [m^3]	Water turbined [m^3]
	Transport Total	0.02	5579	37827	606393	215	211670
2016	Commuting	0.001	616	1897	40448	26	51149
	Scooter	0	0	0	0	0	0
	Car	0.001	334	1735	28595	15	4089
	Public transport	0.000	282	162	11853	11	47060
	Travelling	0.003	623	6048	88920	22	1415
	Plane (Europe)	0.003	623	6048	88920	22	1415
	Plane (intercont.)	0.000	0	0	0	0	0
	Train (CH)	0.000	0	0	0	0	0
	Train (EU)					0	0
	Car (t)					0	0
	Transport 2015					48	52564

Table 3: Flows used

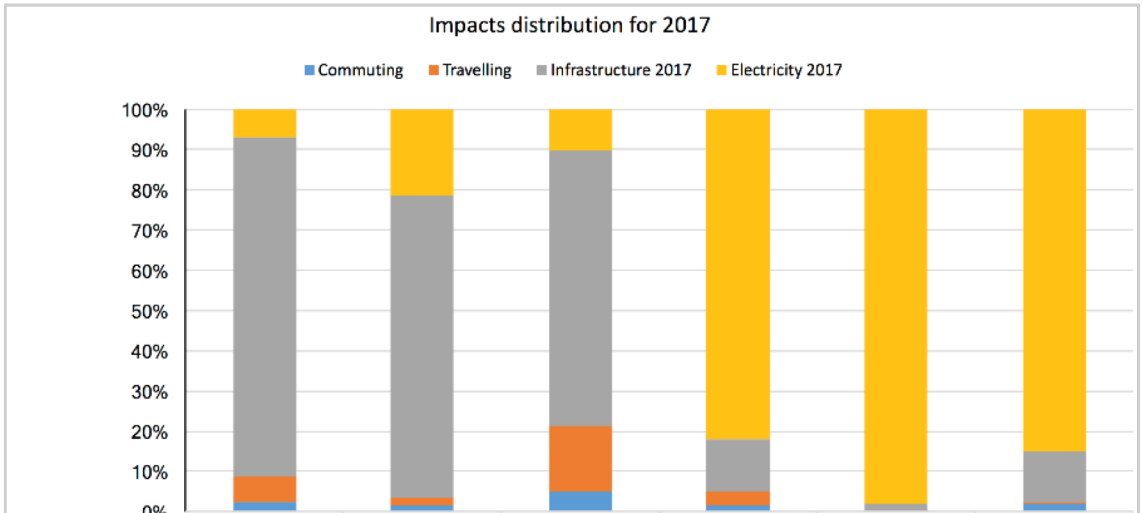
	Flow name
Commuting	
Scooter	transport, scooter [pkm] - CH 11350
Car	transport, passenger car [pkm] - CH 1946
Public transport	transport, regional train, SBB mix [pkm] - CH 6077
Travelling	
Plane (Europe)	operation, aircraft, passenger, Europe [pkm] - RER 1896
Plane (Intercontinental)	transport, aircraft ,passenger, intercontinental [pkm] - RER 1897
Train (CH)	transport, average train, SBB mix [pkm] - CH 11304
Train (Europe)	transport, high speed train [pkm] - DE 6081
Car	transport, passenger car [pkm] - CH 1946
Infrastructure	building, multi-storey [m^3] RE 549
Electricity	Mix 100% hydro local [MJ] - CH (EPFL elec consommée)

LCA of CSO: Excel model

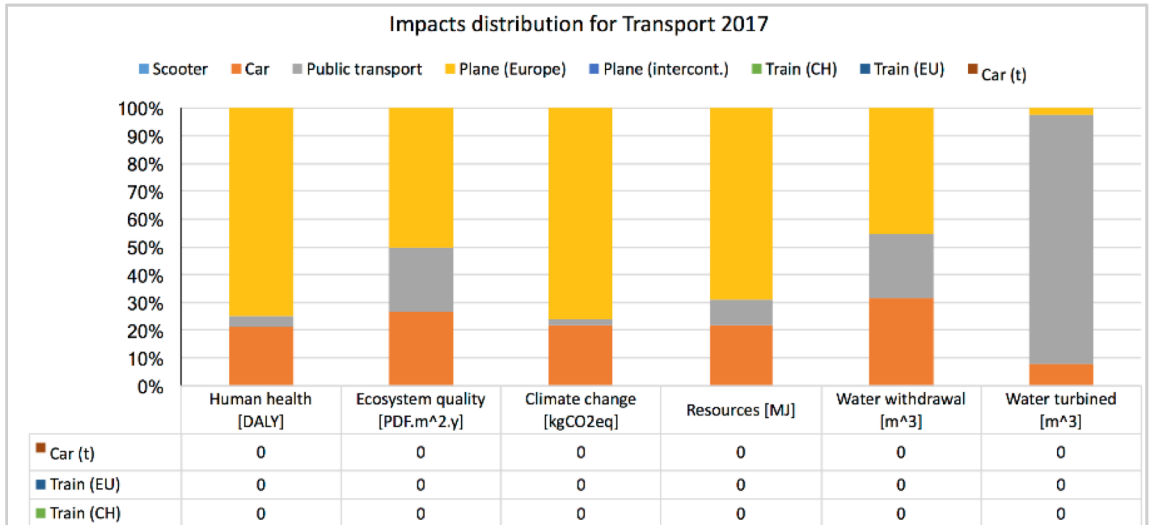
- Outputs



	Human health [DALY]	Ecosystem quality [PDF.m^2.y]	Climate change [kgCO2eq]	Resources [MJ]	Water withdrawal [m^3]	Water turbined [m^3]
Electricity	0,016541215	38948,79045	19358,9914	10386344,12	164450,4486	10194004,41
Infrastructure	0,20345175	136237,95	128133,9	1604832,75	2764,125	1523069,325
Transport	0,019645025	5579,04144	37826,6052	606393,2712	215,3960516	211669,608



	Human health [DALY]	Ecosystem quality [PDF.m^2.y]	Climate change [kgCO2eq]	Resources [MJ]	Water withdrawal [m^3]	Water turbined [m^3]
Electricity 2017	0,003308243	7789,75809	3871,79828	2077268,824	32890,08971	2038800,883
Infrastructure 2017	0,04069035	27247,59	25626,78	320966,55	552,825	304613,865
Travelling	0,00309204	622,8	6048	88920	21,9204	1414,8
Commuting	0,001046206	616,26036	1896,6513	40448,3178	26,44851291	51148,902



	Human health [DALY]	Ecosystem quality [PDF.m^2.y]	Climate change [kgCO2eq]	Resources [MJ]	Water withdrawal [m^3]	Water turbined [m^3]
Car (t)	0	0	0	0	0	0
Train (EU)	0	0	0	0	0	0
Train (CH)	0	0	0	0	0	0
Plane (intercont.)	0	0	0	0	0	0
Plane (Europe)	0,00309204	622,8	6048	88920	21,9204	1414,8
Public transport	0,000173534	282,36096	161,7693	11853,2778	11,11355091	47060,16
Car	0,000872672	333,8994	1734,882	28595,04	15,334962	4088,742
Scooter	0	0	0	0	0	0

LCA of CSO: Excel model

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- Flows: transport

Transportation: Europe and CH	Human health [DALY]	Ecosystem quality [PDF.m^2.y]	Climate change [kgCO2eq]	Resources [MJ]	Water withdrawal [m^3]	Water turbined [m^3]	
Air							
Passenger, aircraft, Europe RER1889 [pkm]	8,5460E-08	1,7200E-02	1,6700E-01	2,4600E+00	5,8460E-04	2,9800E-02	
Passenger, aircraft, intercontinental RER1890 [pkm]	5,4330E-08	1,0900E-02	1,0600E-01	1,5600E+00	3,7100E-04	1,9000E-02	
Freight, aircraft, Europe RER1886 [tkm]	8,5460E-07	1,7200E-01	1,6700E+00	2,4570E+01	5,8360E-03	2,9800E-01	
Freight, aircraft, intercontinental RER1887 [tkm]	5,4330E-07	1,0900E-01	1,0600E+00	1,5620E+01	3,7100E-03	1,9000E-01	
operation, aircraft, passenger, Europe [pkm] - RER 1896	8,589E-08	1,730E-02	1,680E-01	2,470E+00	6,089E-04	3,930E-02	Air continental
transport, aircraft ,passenger, intercontinental [pkm] - RER 1897	5,516E-08	1,140E-02	1,080E-01	1,610E+00	4,328E-04	4,590E-02	Air intercontinental
Rail							
Freight, rail, diesel with particle filter CH11327 [tkm]	6,9060E-08	1,0800E-02	5,1400E-02	7,7800E-01	3,9590E-04	9,4600E-02	
Passenger, average train, SBB mix CH11304 [pkm]	7,9190E-09	1,1900E-02	8,0130E-03	5,0800E-01	4,9130E-04	1,9200E+00	
Passenger, metropolitan train, SBB mix CH11330 [pkm]	8,8680E-09	1,1200E-02	9,4430E-03	4,8300E-01	4,8640E-04	1,6700E+00	
transport, regional train, SBB mix [pkm] - CH 6077	1,1800E-08	1,9200E-02	1,1000E-02	8,0600E-01	7,5570E-04	3,2000E+00	Transports publics
transport, average train, SBB mix [pkm] - CH 11304	7,919E-09	1,190E-02	8,013E-03	5,080E-01	4,913E-04	1,920E+00	Rail domestique
transport, high speed train [pkm] - DE 6081	1,946E-08	9,289E-03	6,410E-02	1,040E+00	2,241E-03	2,040E-01	Rail intercontinental
Road							
Passenger car diesel EURO5 city car CH11782 [pkm]	2,3580E-08	2,3900E-02	5,3600E-02	9,4800E-01	6,2710E-04	1,9300E-01	
Passenger electric bicycle CH11338 [pkm]	1,8540E-08	8,8070E-03	1,6900E-02	3,3000E-01	5,0830E-04	2,9700E-01	
Passenger bicycle CH11342 [pkm]	8,6780E-09	2,8210E-03	9,6310E-03	1,4800E-01	2,2090E-04	1,4100E-01	
Passenger scooter CH11350 [pkm]	7,2260E-08	2,1100E-02	1,2600E-01	1,5700E+00	6,6580E-04	1,1300E-01	
Passenger electric car (VW golf size) certified elec CH11762 [pkm]	6,2980E-08	6,5200E-02	5,2400E-02	1,2600E+00	1,8950E-03	3,5600E+00	
Freight lorry 3.5-16t fleet average RER1941 [tkm]	2,7590E-07	9,8300E-02	2,5900E-01	4,4000E+00	2,2390E-03	4,9500E-01	
Freight lorry >16t fleet average RER1943 [tkm]	1,4390E-07	4,9700E-02	1,3400E-01	2,2400E+00	1,0840E-03	1,6100E-01	
transport, passenger car [pkm] - CH 1946	1,0010E-07	3,8300E-02	1,9900E-01	3,2800E+00	1,7590E-03	4,6900E-01	Voiture
transport, passenger car [pkm] - CH 1946							Véhicules de location
transport, passenger car [pkm] - CH 1946							Véhicules privés
transport, passenger car [pkm] - CH 1946							Véhicules ElectricEasy
transport, scooter [pkm] - CH 11350	7,2260E-08	2,1100E-02	1,2600E-01	1,5700E+00	6,6580E-04	1,1300E-01	Scooter
transport, passenger car, diesel, EURO5 [pkm] - CH 6586	6,3990E-08	3,4900E-02	1,6000E-01	2,7300E+00	1,6140E-03	4,6600E-01	Véhicules EPFL Diesel
transport, passenger car, diesel, EURO5 [pkm] - CH 6586							Véhicules Mobility Diesel
transport, passenger car, petrol, EURO5 [pkm] - CH 6590	7,702E-08	3,570E-02	1,680E-01	2,860E+00	1,681E-03	4,730E-01	Véhicules EPFL Essence
transport, passenger car, petrol, EURO5 [pkm] - CH 6590							Véhicules Mobility essence

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LCA of CSO: Excel model

- Flows: infrastructure and electricity

Infrastructure	Human health [DALY]	Ecosystem quality [PDF.m^2.y]	Climate change [kgCO2eq]	Resources [MJ]	Water withdrawal [m^3]	Water turbined [m^3]
building, multi-storey [m^3] RE 549	3,349E-04	2,243E+02	2,109E+02	2,642E+03	4,550E+00	2,507E+03

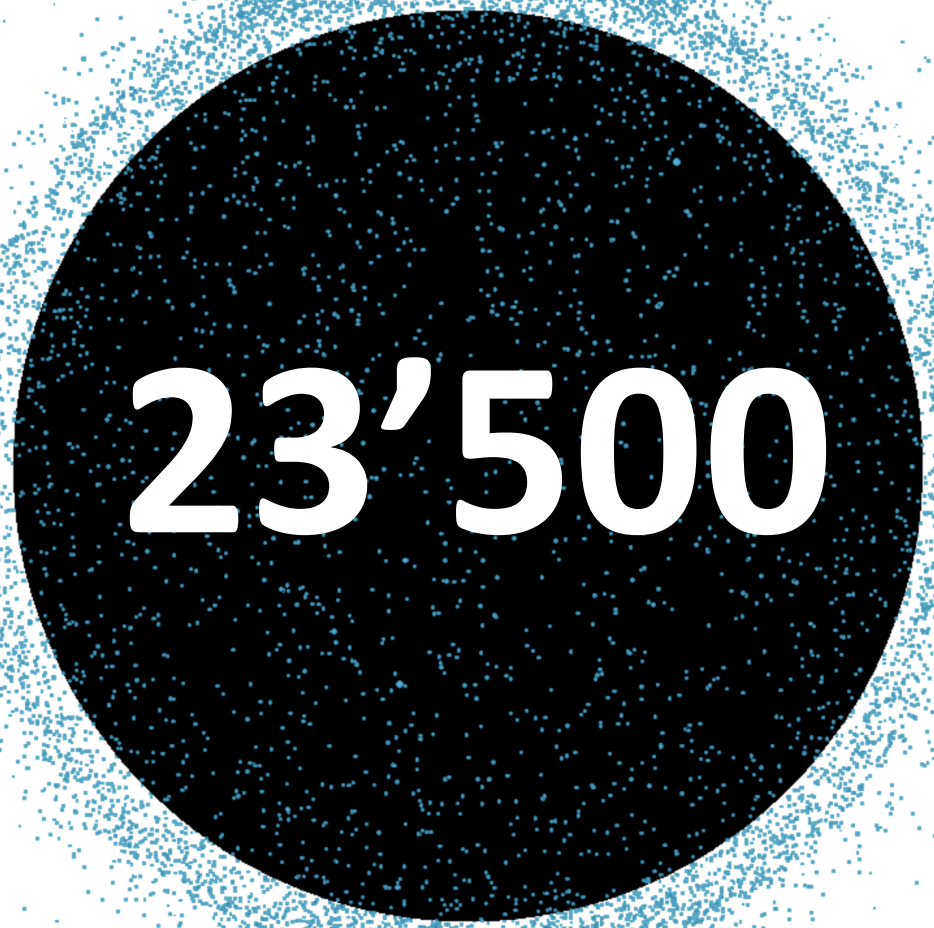
Electricity	Human health [DALY]	Ecosystem quality [PDF.m^2.y]	Climate change [kgCO2eq]	Resources [MJ]	Non-renewable [MJ]	Renewable [MJ]	Water withdrawal [m^3]	Water turbined [m^3]
Mix 100% hydro local [MJ] - CH (EPFL elec consommée)	1,7200E-09	4,0500E-03	2,0130E-03	1,0800E+00	1,7100E-02	1,0600E+00		
Photovoltaics naturemade star [kWh] - CH electricity, production mix photovoltaic at plant [kWh] - CH 1759	5,6460E-08	2,8600E-02	7,6100E-02	1,2200E+00			7,2460E-03	1,5300E+00
Hydroelectricity naturemade star [kWh] - CH electricity, hydropower, at reservoir power plant [kWh] - CH 980	4,8140E-09	4,3160E-03	5,3200E-03	5,5700E-02			9,5060E-05	8,3900E-01
electricity, consumer mix [kWh] - CH EcoInvent 2.2 11360	8,3120E-08	5,6300E-02	1,1600E-01	7,6800E+00			8,0430E-03	8,7500E+00

- When possible, same flows as Sustainable Campus

Further work

- LCA for space is very involved but trends have been highlighted

- Further develop and refine the model
- Implement ESA databases
- Update EPFL flows
- Check for implementation of new impacts (orbital use and debris indicator)



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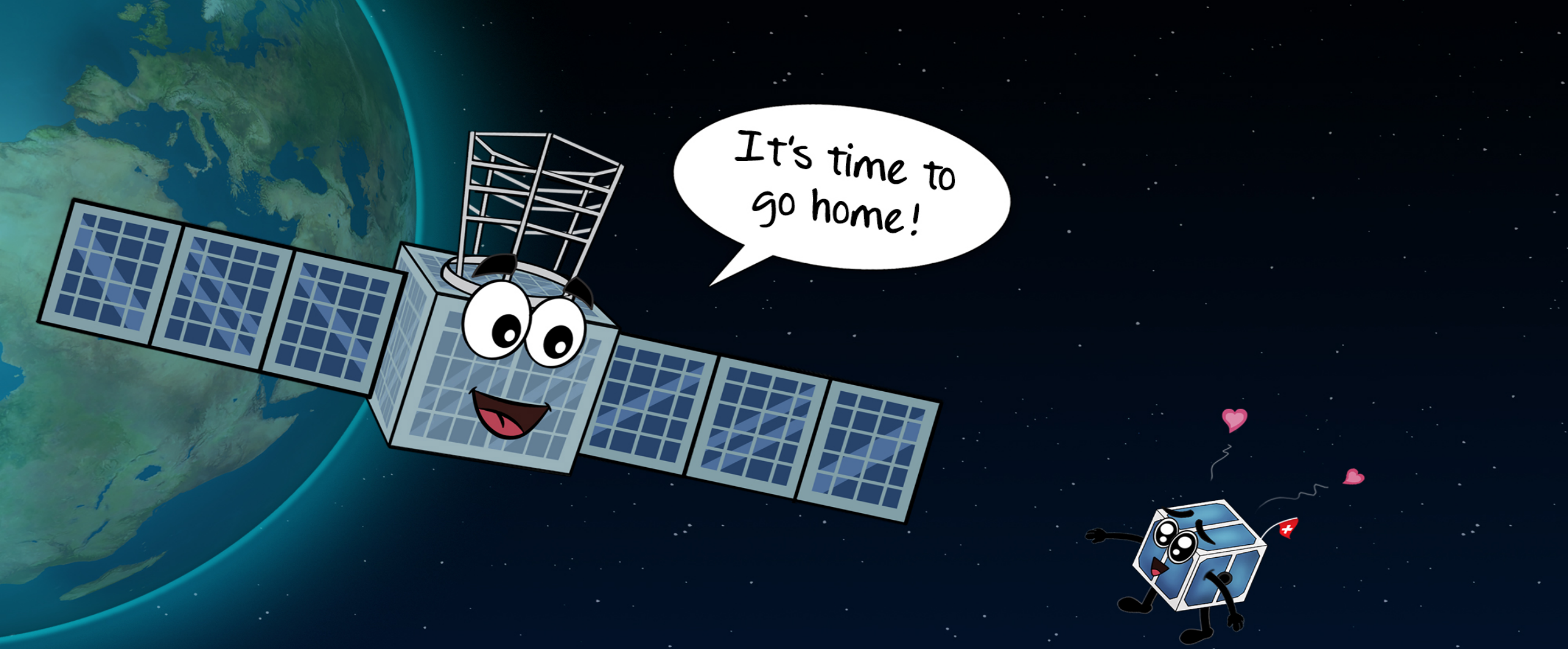

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