Introduction to MELiSSA Project

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Ljubjana


MARS:EXPLORATION
PRECVRSOR
MISSIONS
ESA:COVNCIL


MELISSA : CONSTRVCTION
JOVRNEY

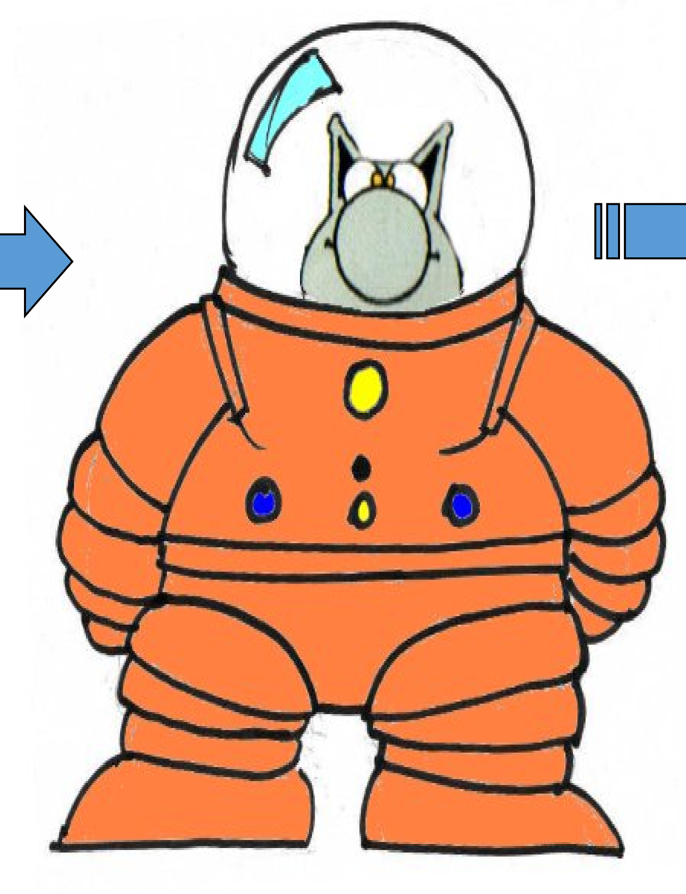
Mass Balance

Inputs:

O_2

Water

Food



Outputs:

Urine

Feaces

CO_2

Transpiration

Contaminants

(Microbial
Chemical)

Some Basic Calculations

- Metabolic Consumables:
  - For 5kg/d/pers, 6 crew members, 1000 days missions (Mars)

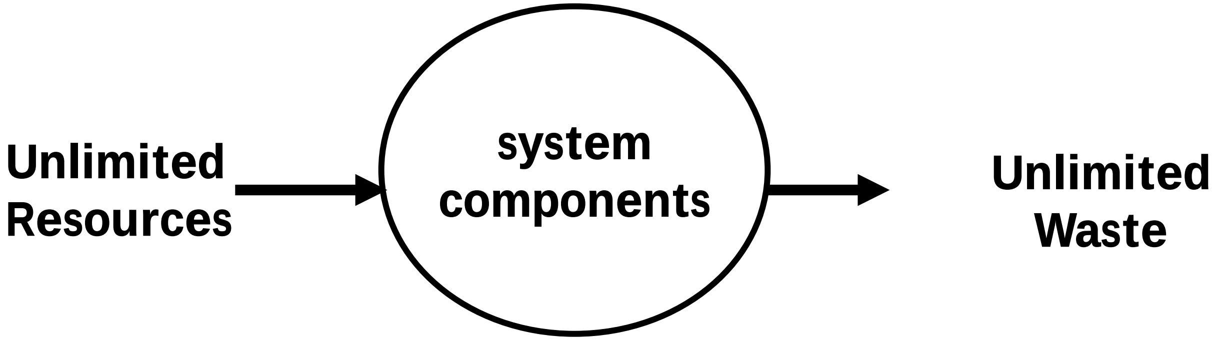
→ **30 000 kg,**

- Including hygiene items:
  - Same mission configuration (+20kg/water/d)

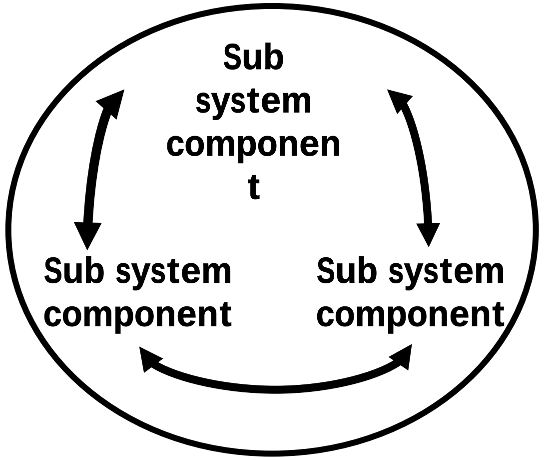
→ **132 000 Kg,**

But current launcher can only drop 9 t on the Moon !!!!

Today: Open System (i.e. juvenile)



Tomorrow : Closed (i.e. mature)



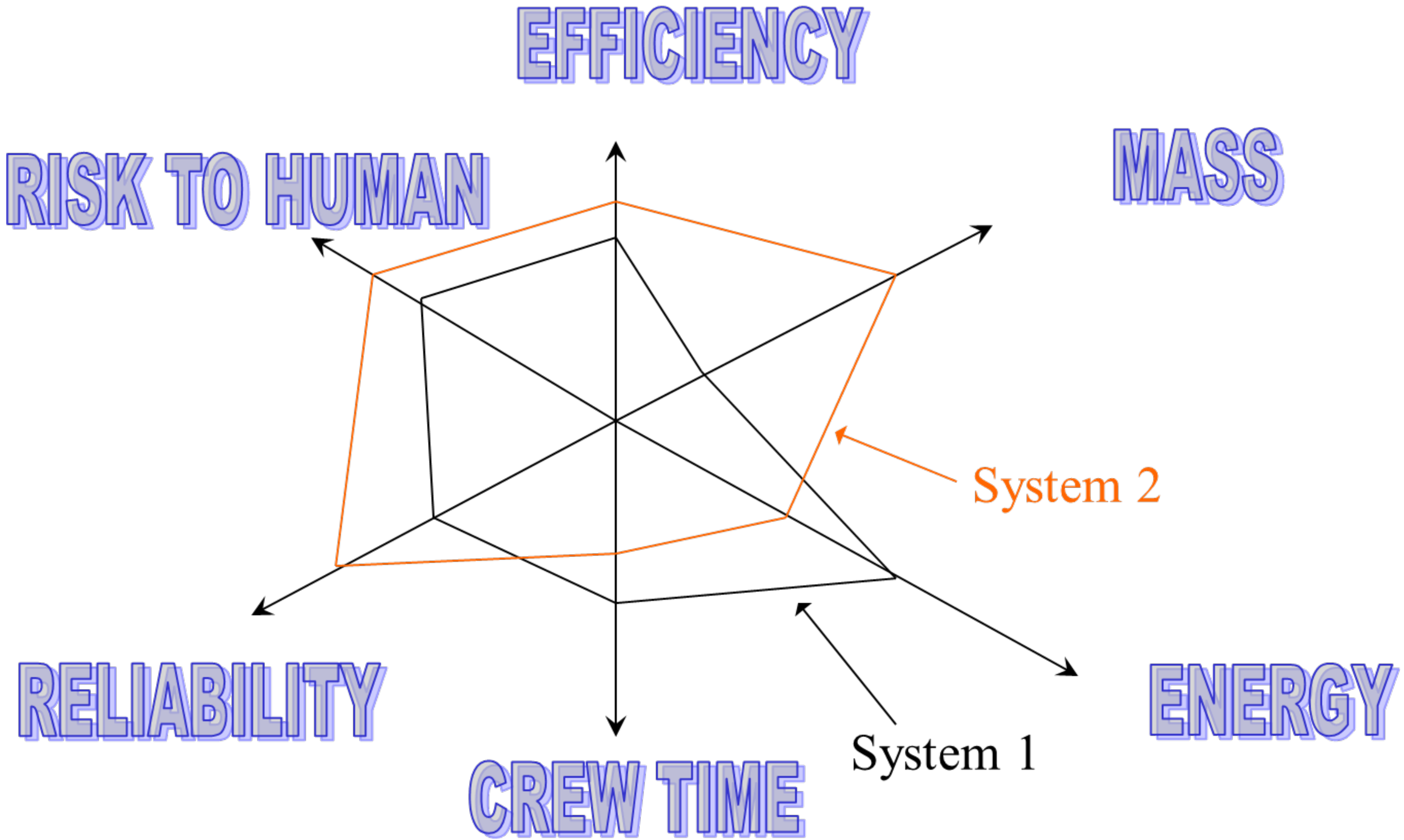
- Low consumption of resources
- Quasi-cyclical flows of materials

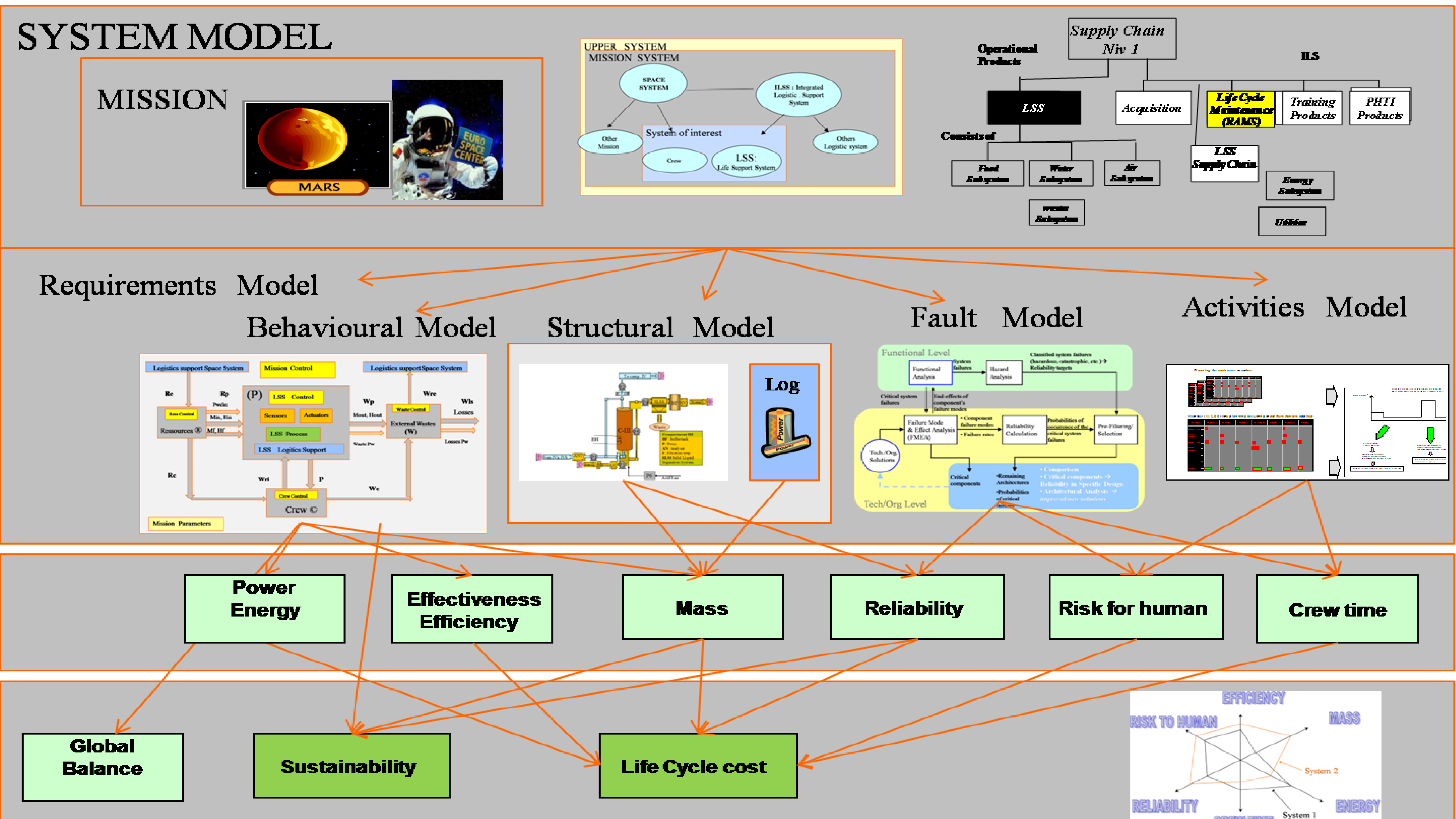
the challenge

How to assemble processes and technology to reach the highest possible level of closure and the best set of ALiSSE Criteria.

ALiSSE Criteria

- Metric to evaluate and compare ECLSS:
  - Multi-parameters,
    - Efficiency,
    - Mass,
    - Energy,
    - Safety,
    - Crew time.




SYSTEM MODEL
MISSION
MARS
EURO SPACE CENTER
UPPER SYSTEM
MISSION SYSTEM
SPACE SYSTEM
ILSS : Integrated Logistic . Support System
Other Mission
System of interest
Crew
LSS: Life Support System
Others Logistic system
Supply Chain Niv 1
Operational Products
ILS
LSS
Acquisition
Life Cycle Maintenance (RAMS)
Training Products
PHTI Products
Consists of
Food Subsystem
Water Subsystem
Air Subsystem
LSS Supply Chain
Energy Subsystem
Utilities
Requirements Model
Behavioural Model
Structural Model
Fault Model
Activities Model
Logistics support Space System
Mission Control
LSS Control
Sensors
Actuators
LSS Process
LSS Logistics Support
Waste Control
External Wastes (W)
Resources ®
Crew Control
Crew ©
Mission Parameters
Log
Power
Functional Level
Functional Analysis
Hazard Analysis
Failure Mode & Effect Analysis (FMEA)
Reliability Calculation
Pre-Filtering/ Selection
Tech./Org Solutions
Tech/Org Level
Power Energy
Effectiveness Efficiency
Mass
Reliability
Risk for human
Crew time
Global Balance
Sustainability
Life Cycle cost
EFFICIENCY
RISK TO HUMAN
MASS
RELIABILITY
ENERGY
System 2
System 1

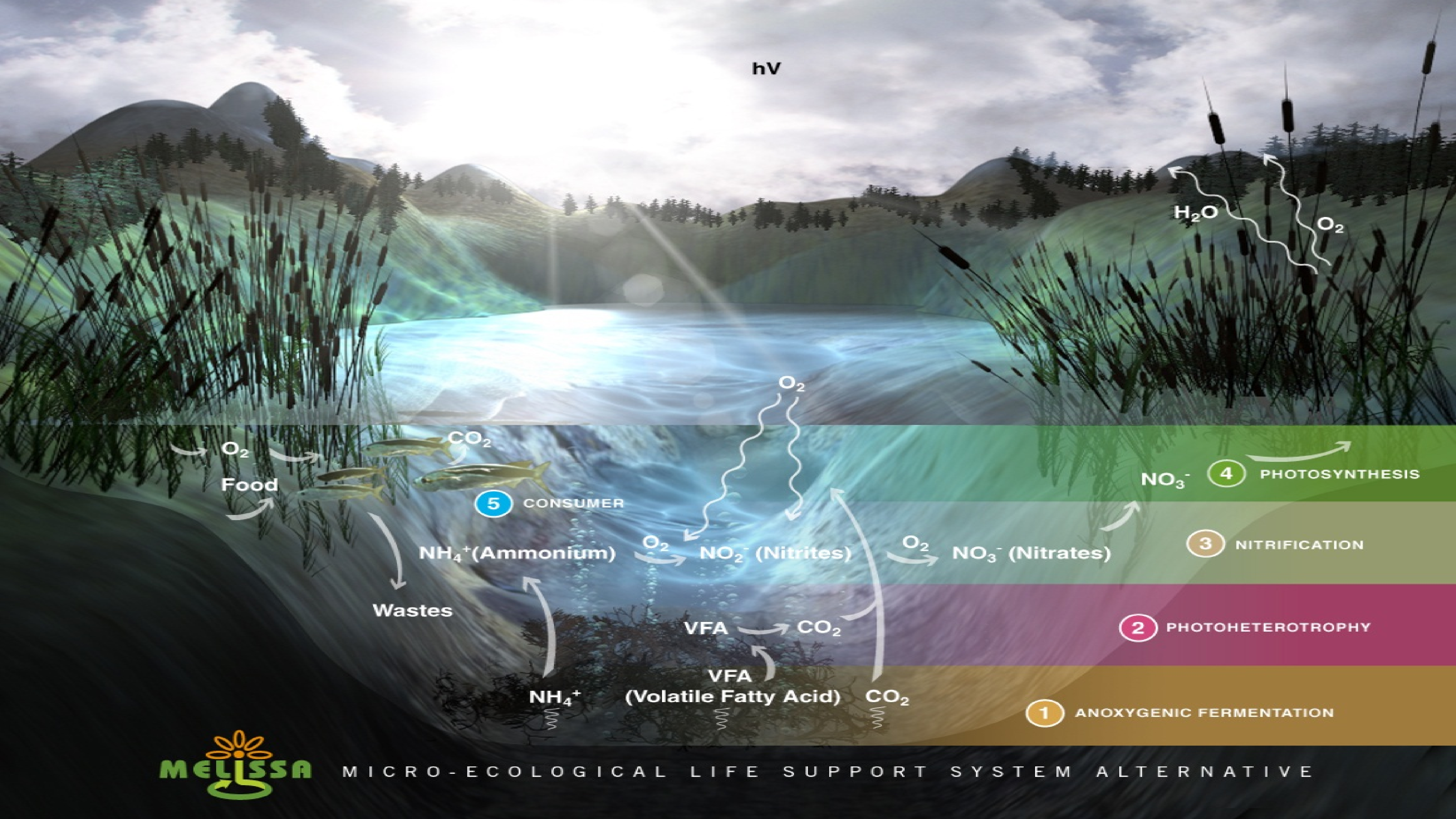
The Food issue

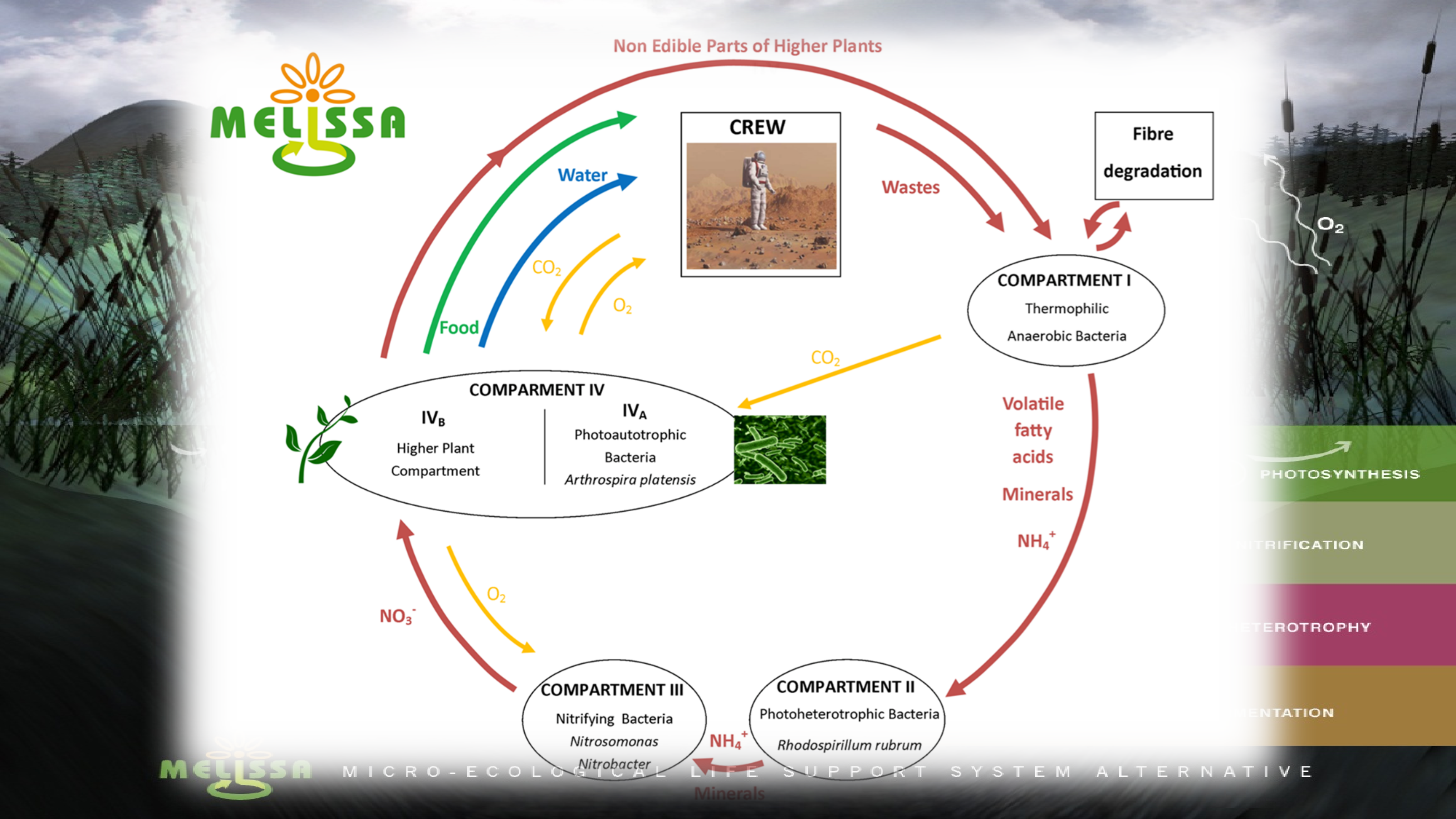
- No high degree of closure without Food production,
- Food means Biological processes,
- Biological process means:
  - Complex molecule (>>>> O2 or H2O),
  - Very high and very slow dynamics,
  - Potential nature changes,
- So far, same logic applies for waste recycling !!

MELiSSA Project

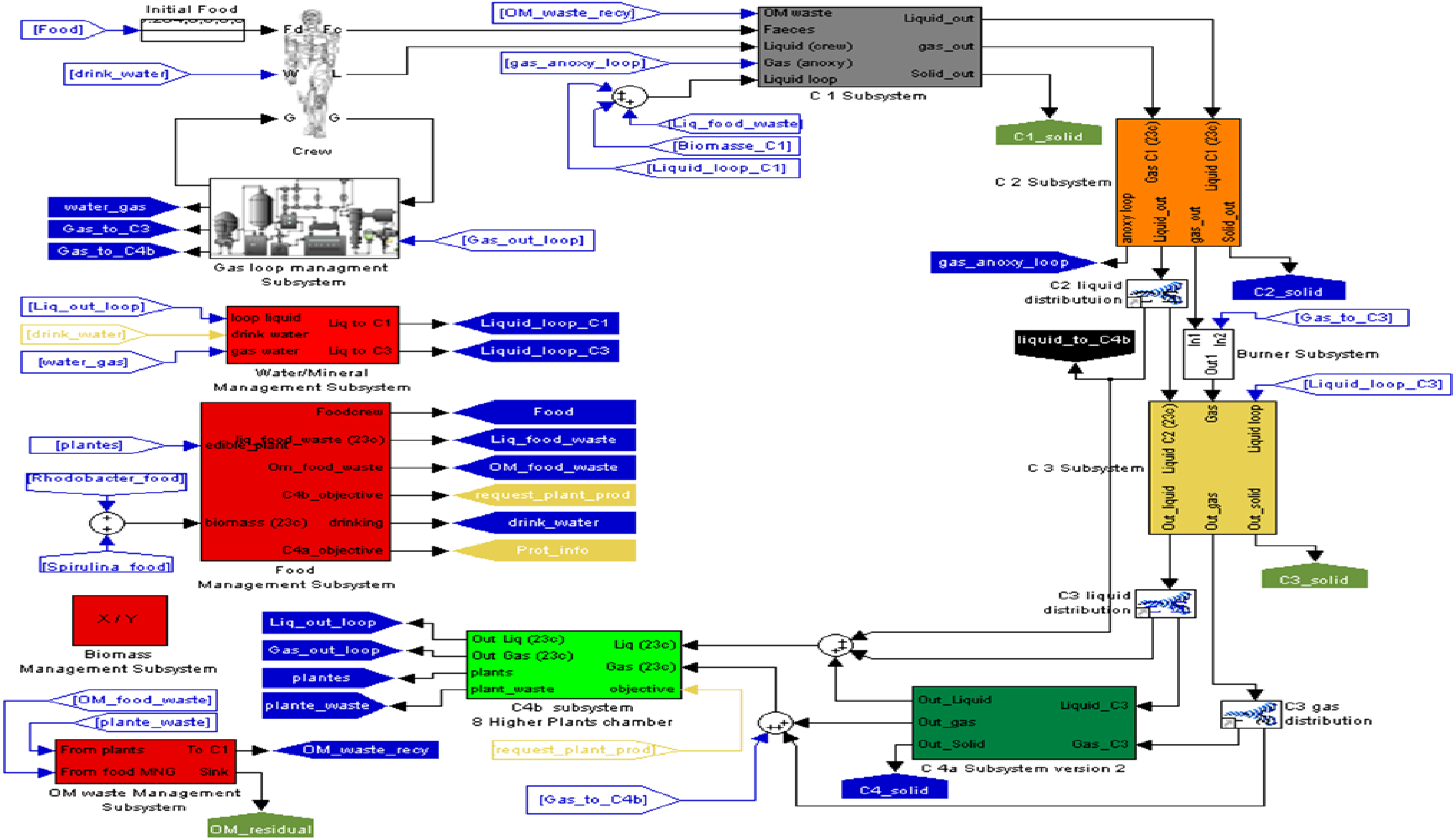
- Started in 1989
- ~ 30 organisations,
- 14 countries (this morning…..)

A Team Work


hV
H_2O
O_2
O_2
CO_2
O_2
Food
5 CONSUMER
NO_3^-
4 PHOTOSYNTHESIS
NH_4^+(Ammonium)
O_2
NO_2^- (Nitrites)
O_2
NO_3^- (Nitrates)
3 NITRIFICATION
Wastes
VFA
CO_2
2 PHOTOHETEROTROPHY
VFA
(Volatile Fatty Acid)
NH_4^+
CO_2
1 ANOXYGENIC FERMENTATION
MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE



MELISSA
Non Edible Parts of Higher Plants
CREW
Wastes
Fibre degradation
O2
Water
Food
CO2
O2
COMPARTMENT I
Thermophilic
Anaerobic Bacteria
CO2
Volatile fatty acids
Minerals
NH4+
COMPARMENT IV
IVB
Higher Plant Compartment
IVA
Photoautotrophic Bacteria
Arthrospira platensis
NO3-
O2
COMPARTMENT III
Nitrifying Bacteria
Nitrosomonas
Nitrobacter
NH4+
Minerals
COMPARTMENT II
Photoheterotrophic Bacteria
Rhodospirillum rubrum
PHOTOSYNTHESIS
MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

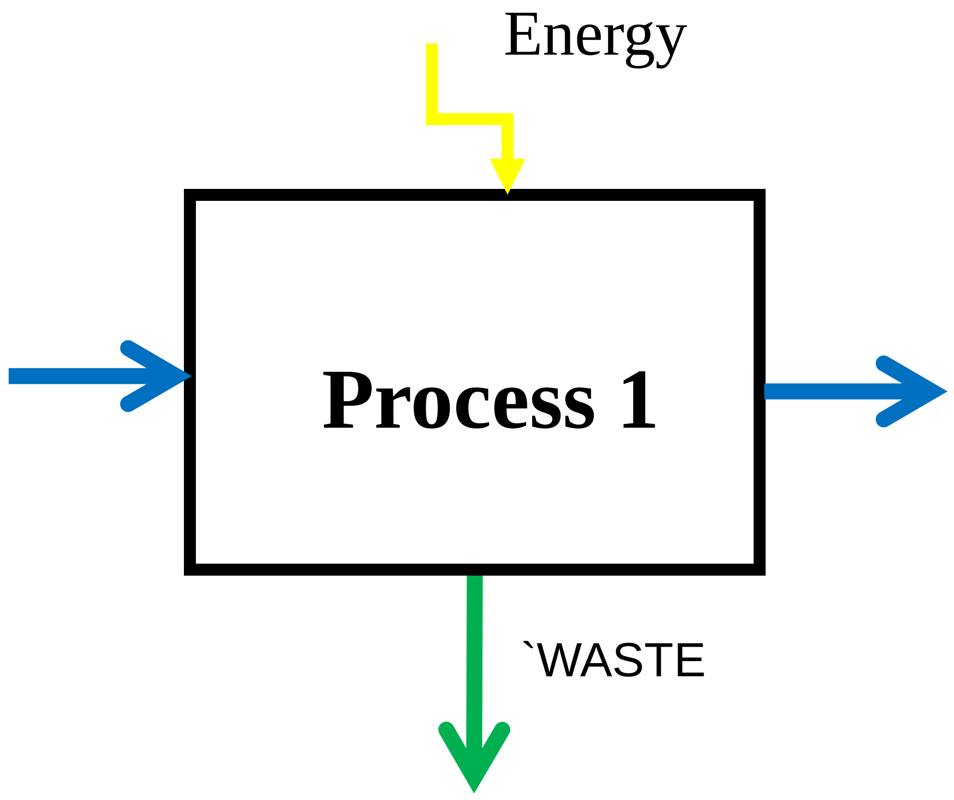

Initial Food
[Food]
Fd
Fc
[drink_water]
W
L
G
G
Crew
water_gas
Gas_to_C3
Gas_to_C4b
Gas loop managment Subsystem
[Gas_out_loop]
[OM_waste_recy]
OM waste
Faeces
Liquid (crew)
Gas (anoxy)
Liquid loop
Liquid_out
gas_out
Solid_out
C 1 Subsystem
[gas_anoxy_loop]
[Liq_food_waste]
[Biomasse_C1]
[Liquid_loop_C1]
C1_solid
C 2 Subsystem
anoxy loop
Liquid_out
Gas C1 (23c)
gas_out
Liquid C1 (23c)
Solid_out
gas_anoxy_loop
C2 liquid distributuion
C2_solid
[Gas_to_C3]
liquid_to_C4b
In1
In2
Out1
Burner Subsystem
[Liquid_loop_C3]
[Liq_out_loop]
[drink_water]
[water_gas]
loop liquid
drink water
gas water
Liq to C1
Liq to C3
Water/Mineral Management Subsystem
Liquid_loop_C1
Liquid_loop_C3
Foodcrew
edible_plant
Liq_food_waste (23c)
Om_food_waste
C4b_objective
biomass (23c)
drinking
C4a_objective
Food Management Subsystem
[plantes]
[Rhodobacter_food]
[Spirulina_food]
Food
Liq_food_waste
OM_food_waste
request_plant_prod
drink_water
Prot_info
C 3 Subsystem
Liquid C2 (23c)
Gas
Liquid loop
Out_liquid
Out_gas
Out_solid
C3_solid
C3 liquid distribution
X / Y
Biomass Management Subsystem
Liq_out_loop
Gas_out_loop
plantes
plante_waste
Out Liq (23c)
Out Gas (23c)
plants
plant_waste
Liq (23c)
Gas (23c)
objective
C4b subsystem
8 Higher Plants chamber
[OM_food_waste]
[plante_waste]
From plants
From food MNG
To C1
Sink
OM waste Management Subsystem
OM_waste_recy
OM_residual
[request_plant_prod]
[Gas_to_C4b]
Out_Liquid
Out_gas
Out_Solid
Liquid_C3
Gas_C3
C 4a Subsystem version 2
C4_solid
C3 gas distribution

The Scientific Challenges

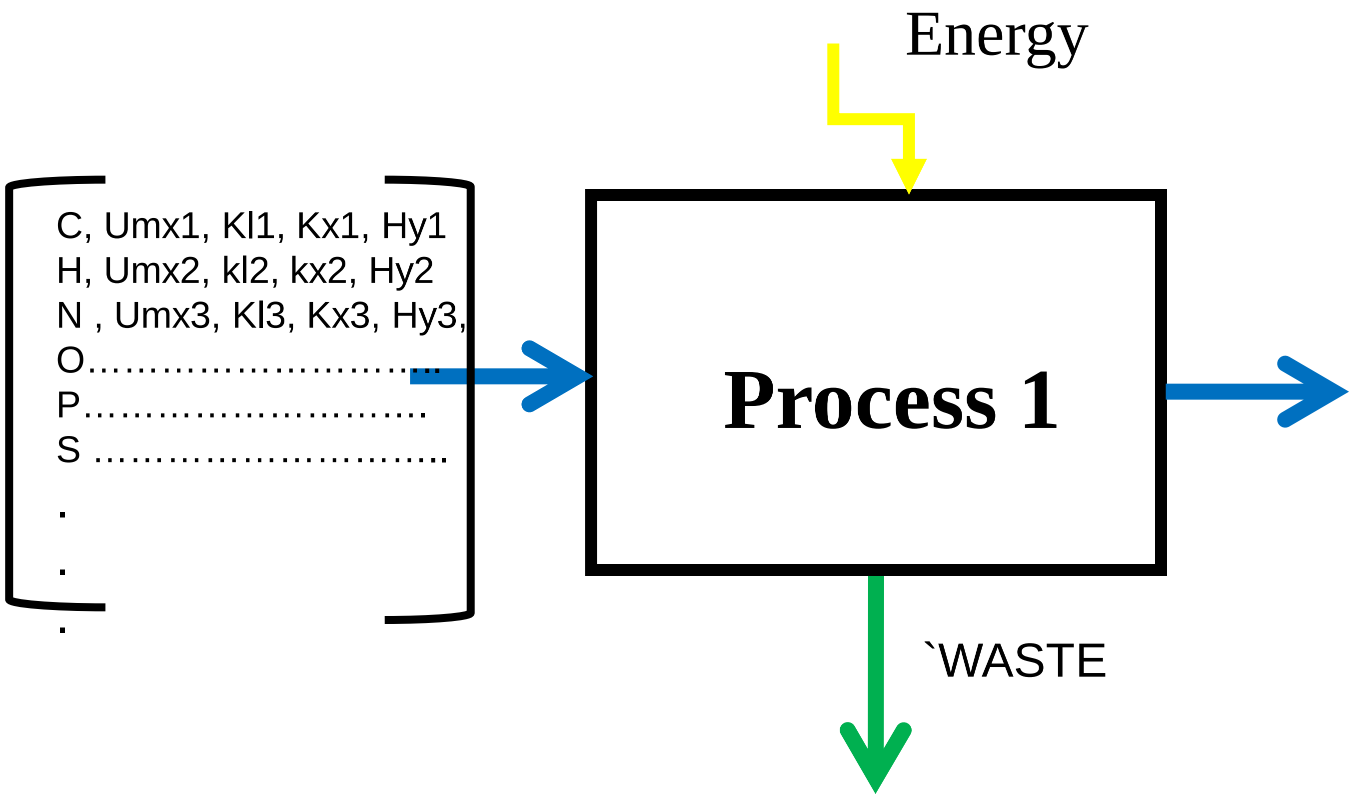
- Demonstration of the efficiency of each sub-process,
- Compatibility between processes (static and dynamic),
- Modelling and control of biological processes,
- Limitation/poisoning via traces elements,
- Very long term drift,
- Biosafety,
- Crew Acceptance of recycled products,
- …..

Step by Step

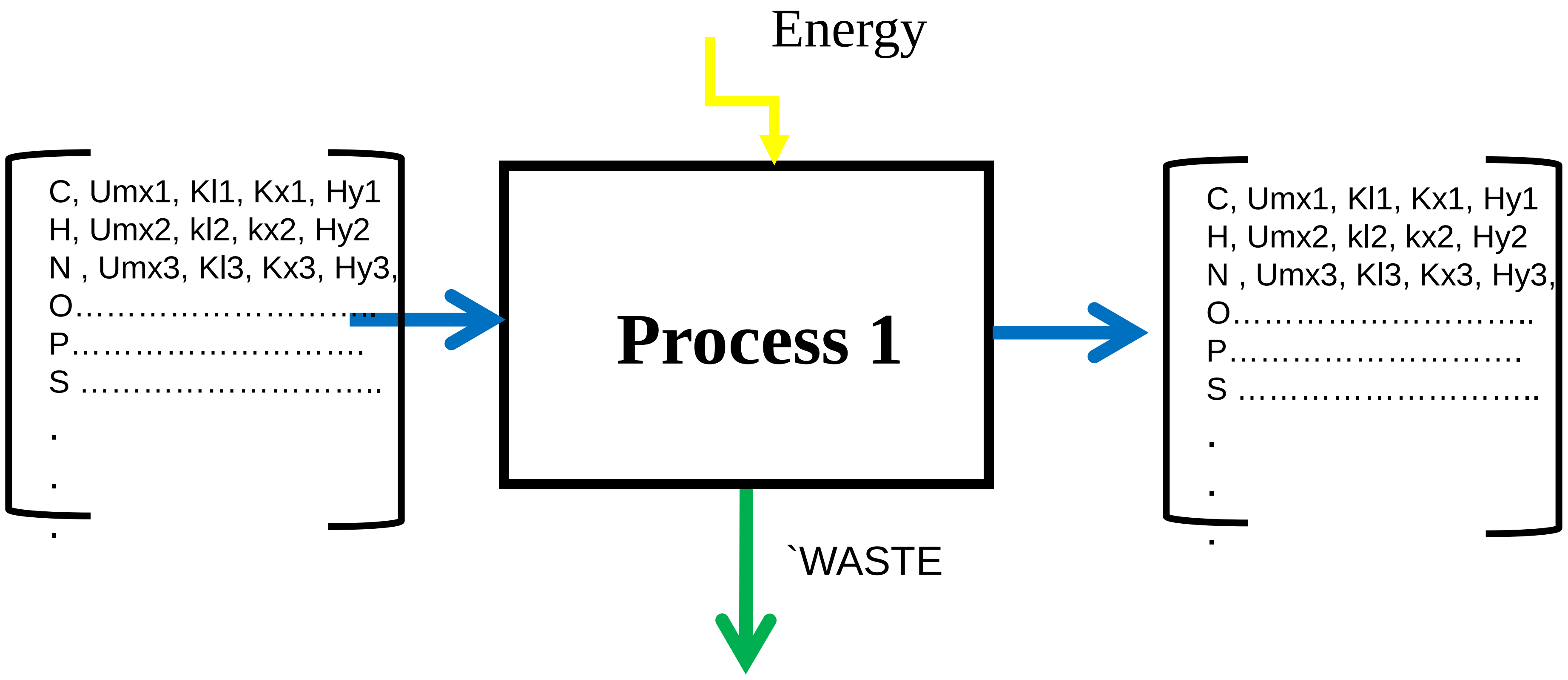
LAVOISIER' approach



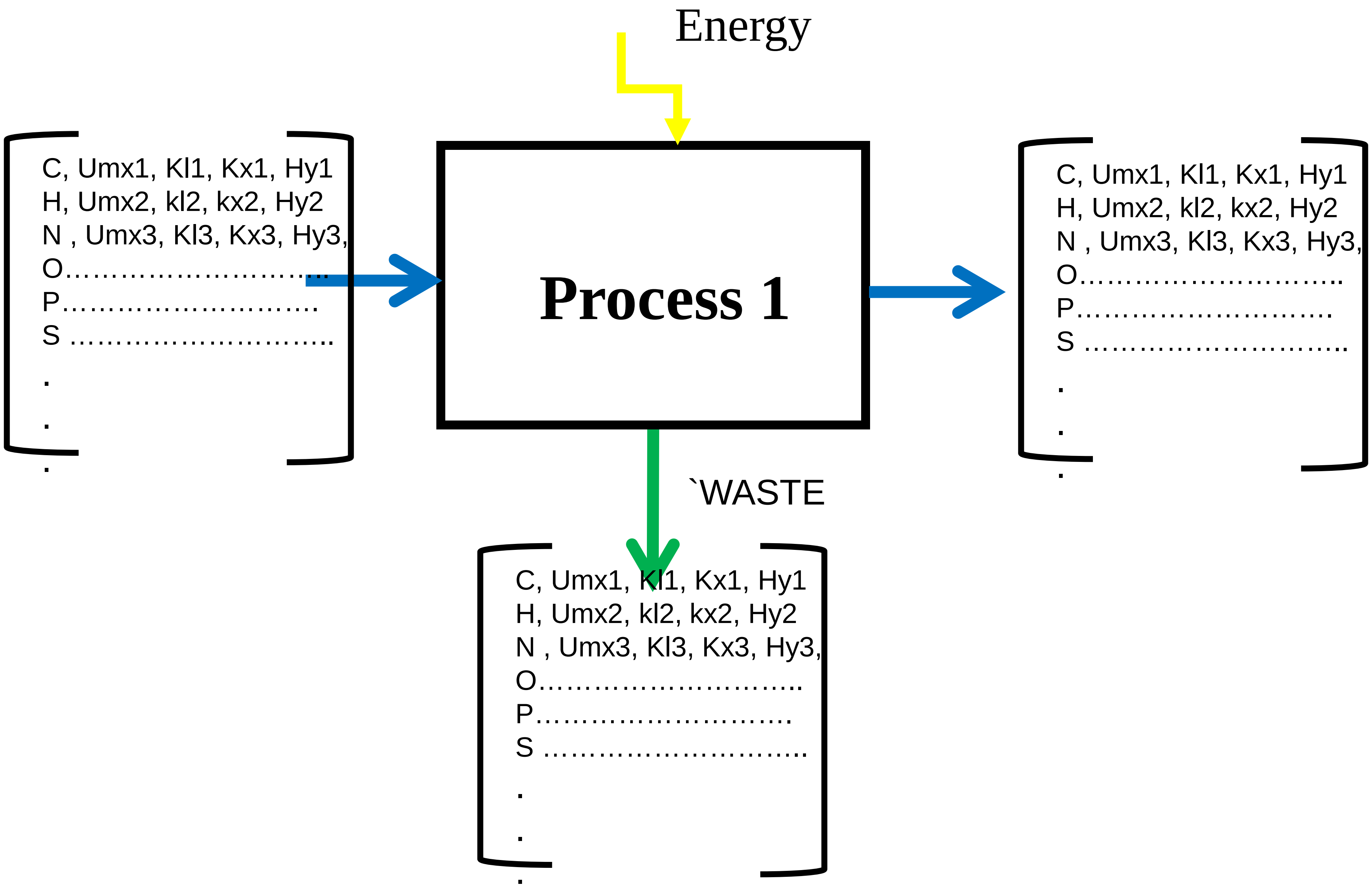
LAVOISIER' approach



LAVOISIER' approach



LAVOISIER' approach



LAVOISIER' approach

C, Umx1, Kl1, Kx1, Hy1
H, Umx2, kl2, kx2, Hy2
N , Umx3, Kl3, Kx3, Hy3,
O………………………..
P……………………….
S ………………………..
.
.
.

LAVOISIER' approach

LAVOISIER' approach

C, Umx1, Kl1, Kx1, Hy1
H, Umx2, kl2, kx2, Hy2
N , Umx3, Kl3, Kx3, Hy3,
O…………………………..
P…………………………
S …………………………..
.
.
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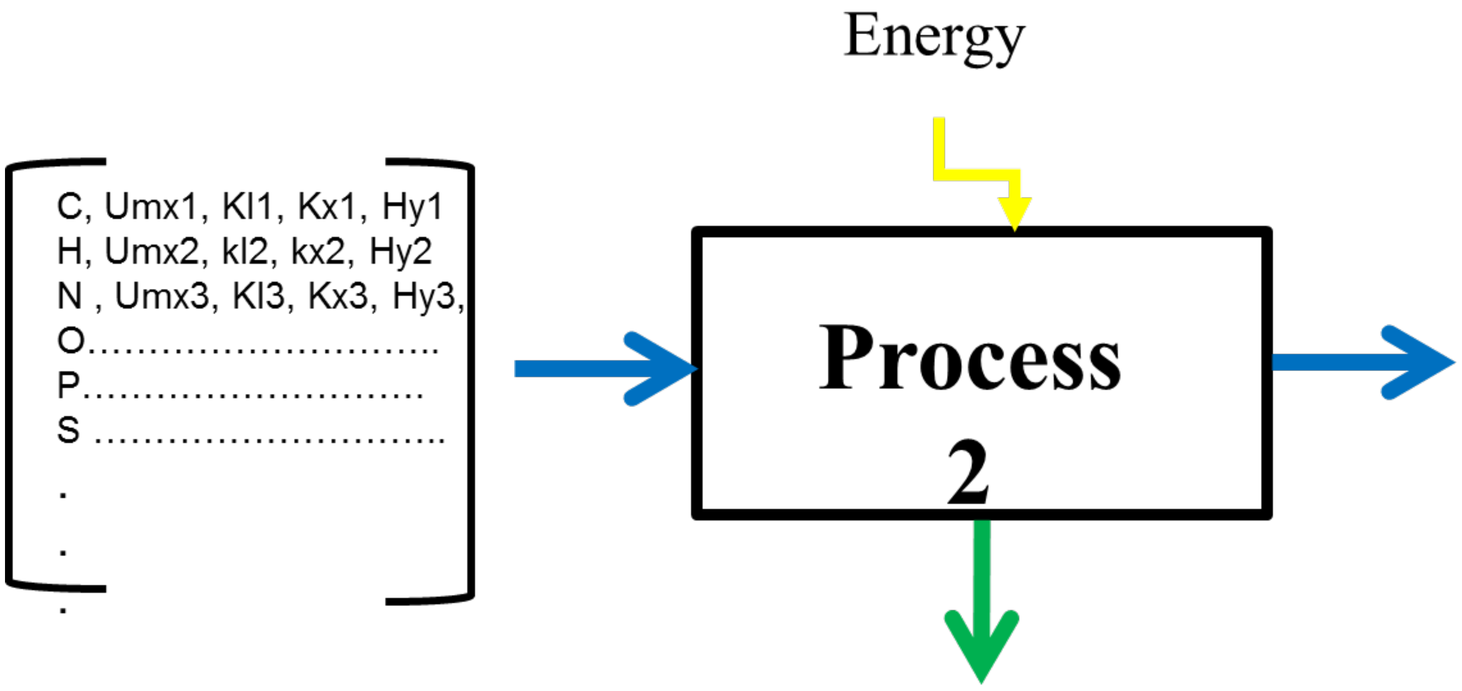
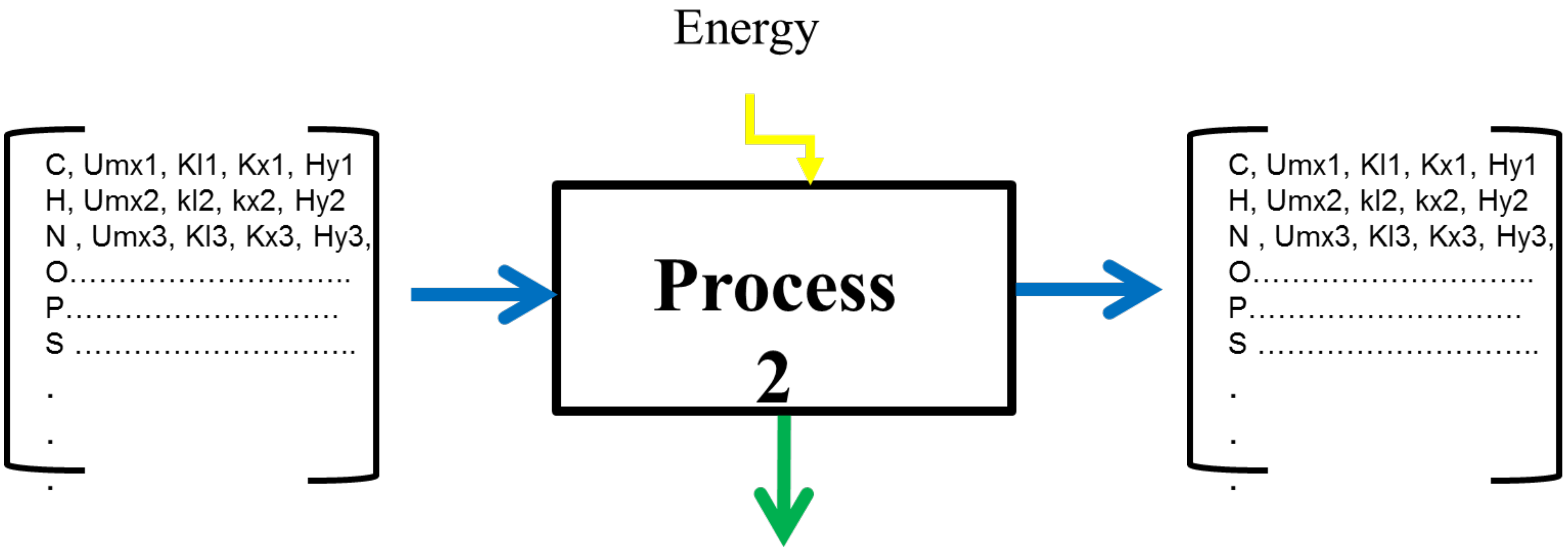
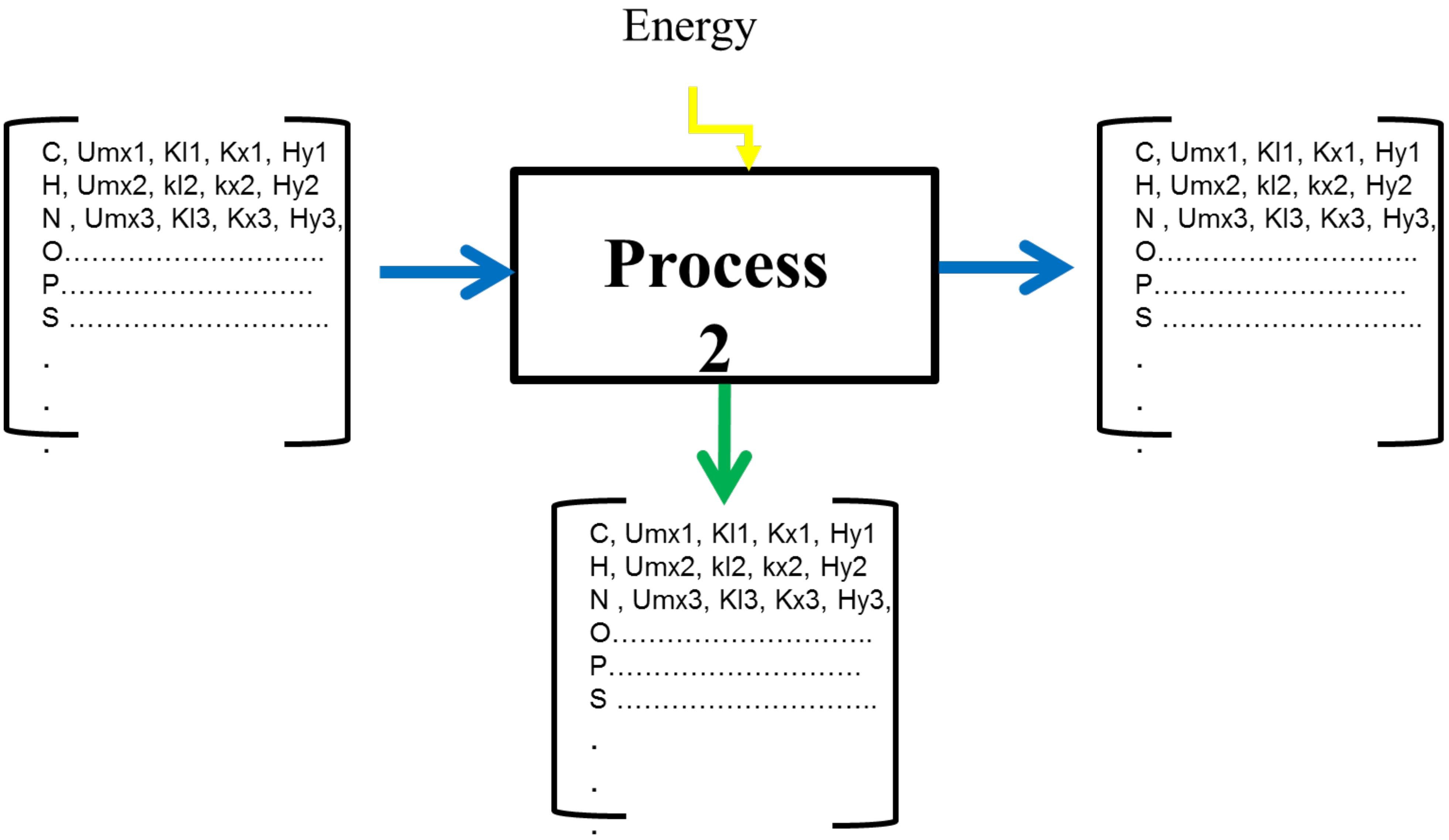
LAVOISIER' approach



LAVOISIER' approach

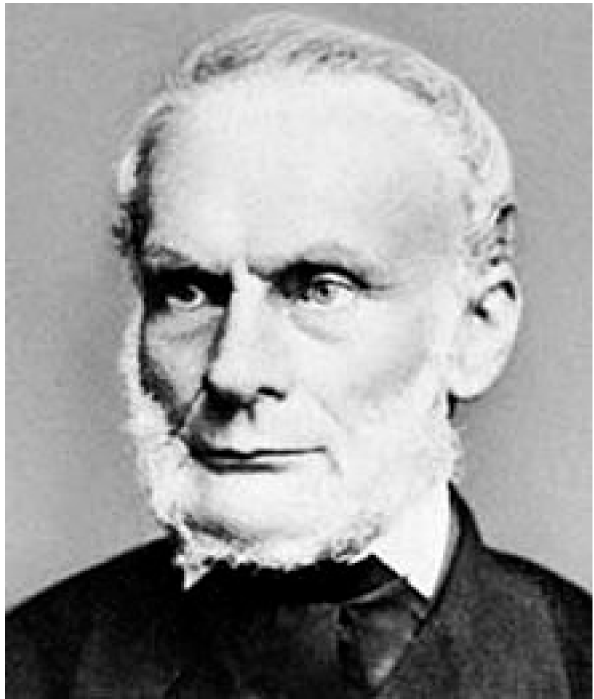


LAVOISIER' approach



Modelling and Simulation Approach

- From one microorganisms modelling to a functional community modelling,
- From CHNOSP to the “complete” Mendeleev table,
- From Mass balance/Monod to Thermodynamical models (i.e R. Clausius),
- Modelling of genetic/transcriptomic evolution,



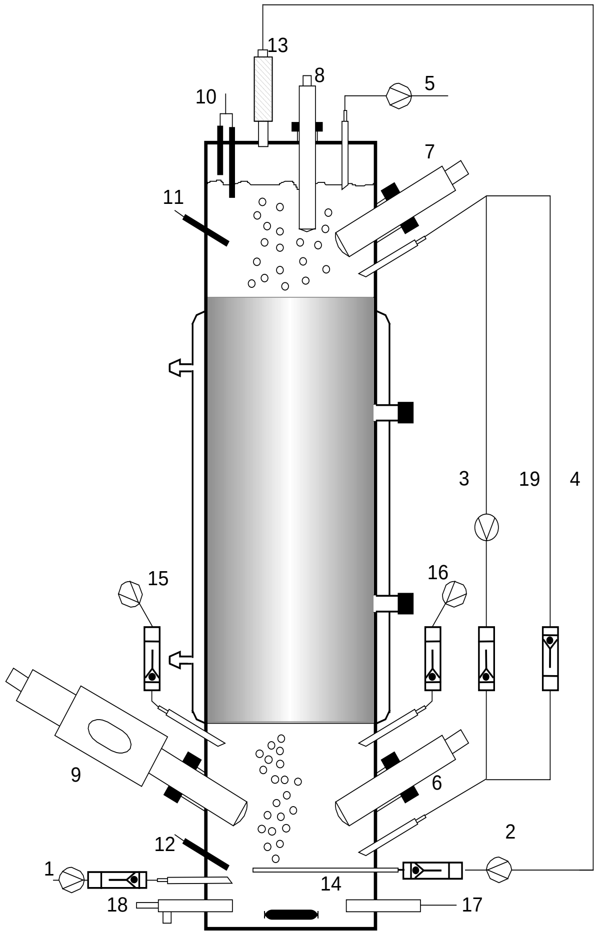
Urine: Any Interest ?

- Potential Interest depending of the space mission :
  - Water,
  - Nitrogen gas (N2),
  - Nitrates,
  - Energy.

  - As well as for Earth : Reduced Environmental Impact with Green algae, odors, pharmaceuticals, hormones,…

Nitrogen Transformation

NH_4^+ ➡ **COMPARTMENT III** ➡ NO_3^-

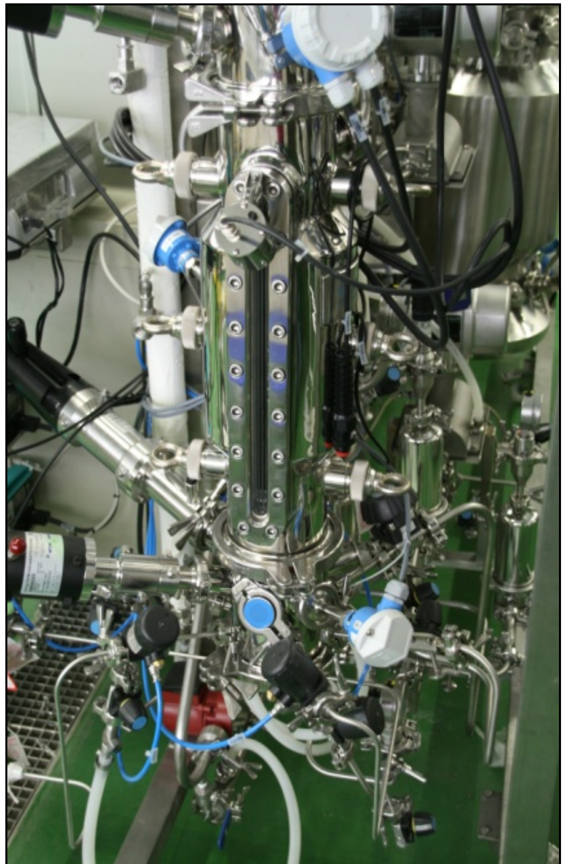


Nitrobacter winogradskyi

$NH_4^+ \longrightarrow NO_2^- \longrightarrow NO_3^-$

Nitrosomonas europaea

- Packed-bed reactors
  Immobilized cells
- Pilot scale reactors
- Several reactors
- Biofilm control



Model calibration/validation

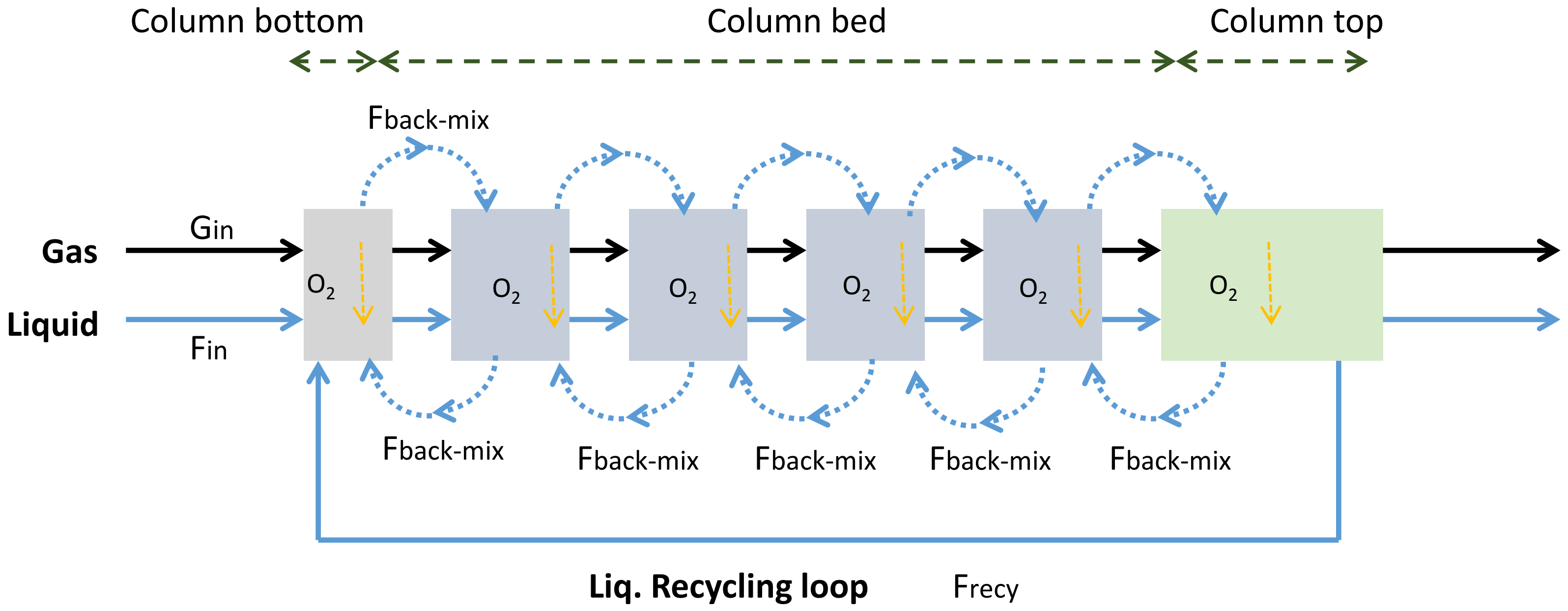
Biological parameters:

- Pures cultures (batch reactors)
- Coculture (fixed-bed reactor and bioreactors

Physical parameters:

- DTS: characterisation of the hydrodynamic model
- kLa: characterisation of the gas/liquid transfer rate

N-tanks in series



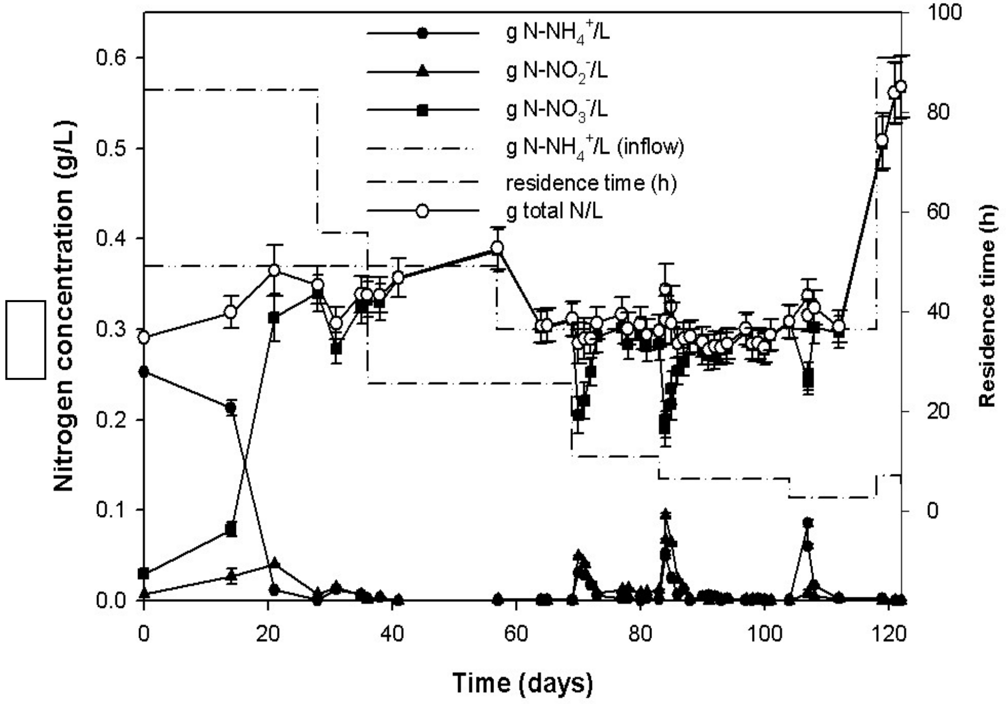
Mass balance equation:

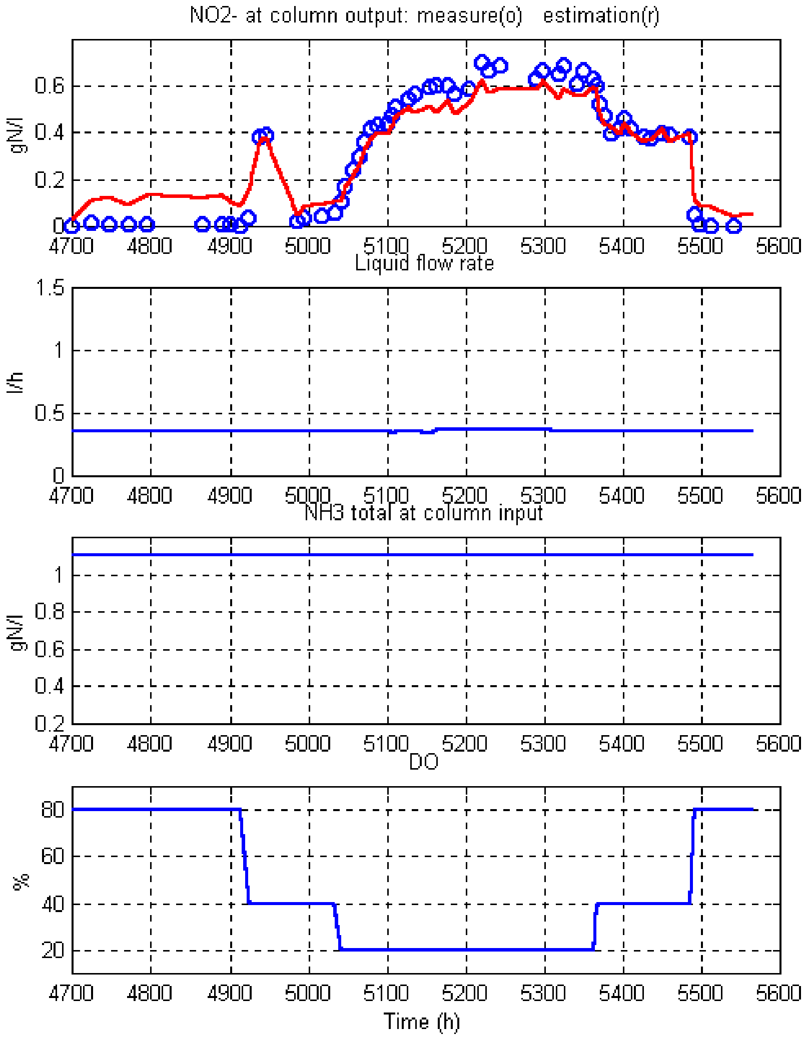
$$\frac{(dVL^n.S^n)}{dt} = (F_{IN} + F_{RECY} + F_{Backmix}).(S^{(n-1)} - S^n) + F_{Backmix}.(S^{(n+1)} - S^n)$$ (in-out) mass flow

$$+ VL^n.RLs^n + VL^n.RFs^n$$ Bioreaction (Pirt model)

$$+ VL^n.EGLs^n$$ Gaz/liquid exchange ratio

High Level of Prediction



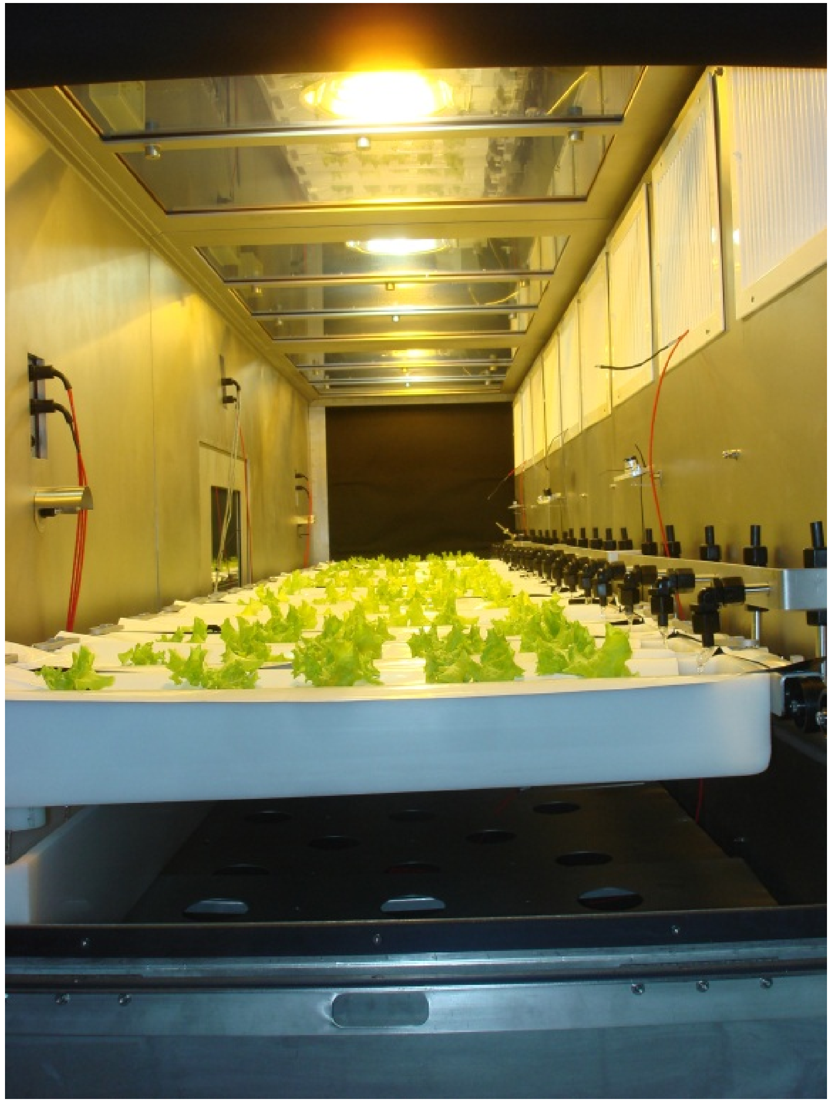


Variation of the Dissolved Oxygen

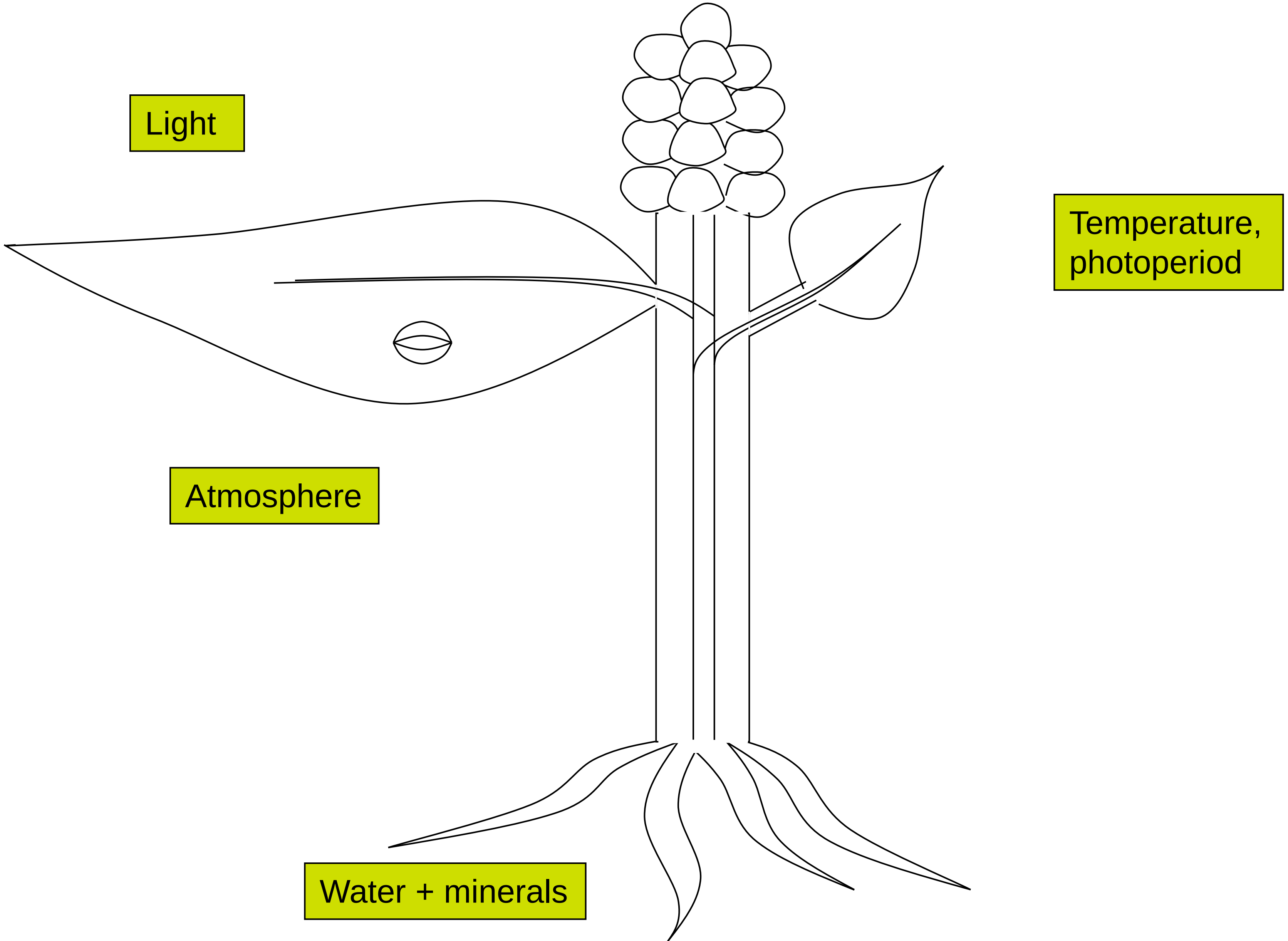
The Producer

- Food, oxygen and water productions are organised via two processes:
  - An Algae compartment (IV a)
  - An Higher plant compartment (IV b)

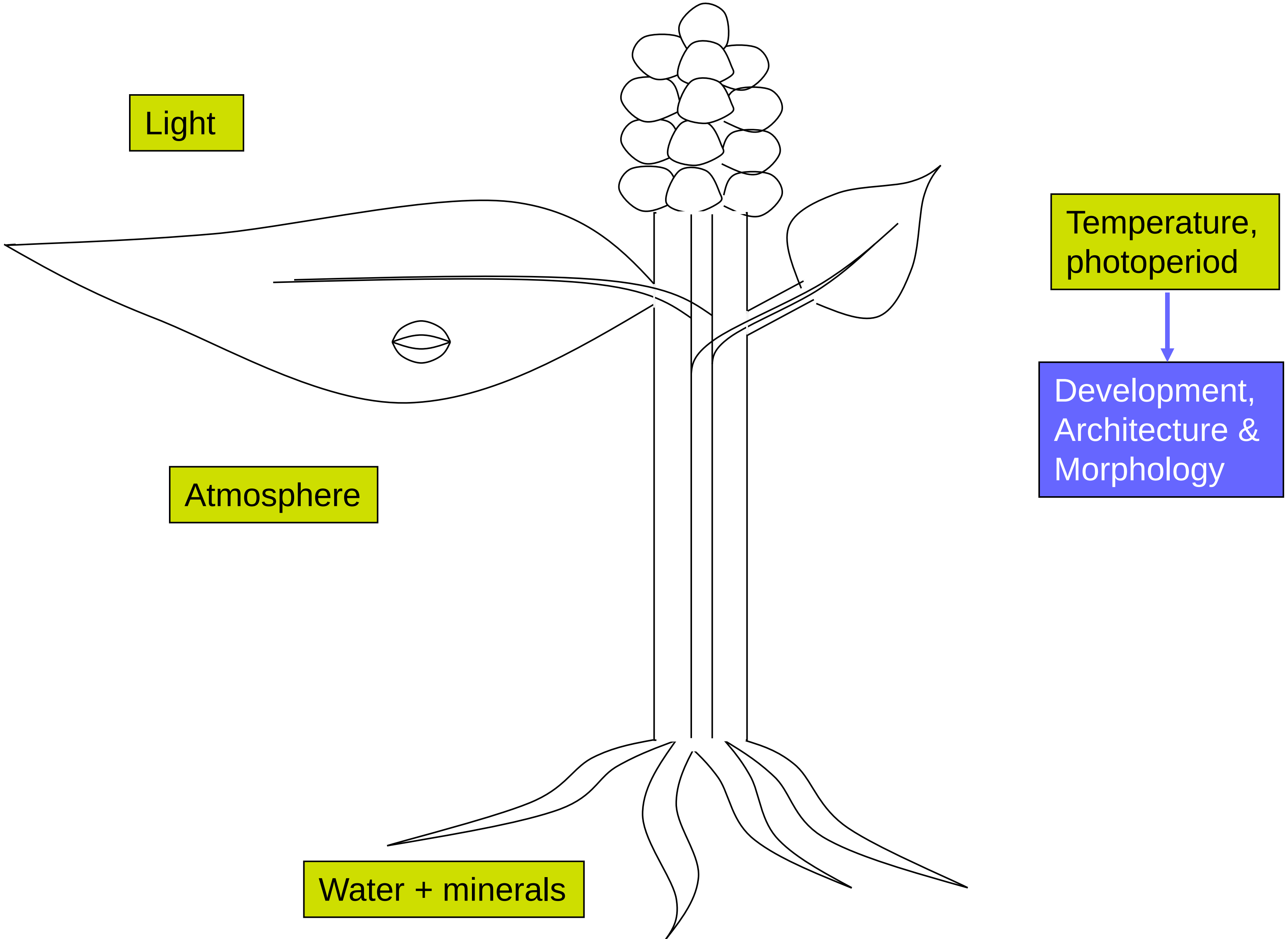
Higher Plants Research



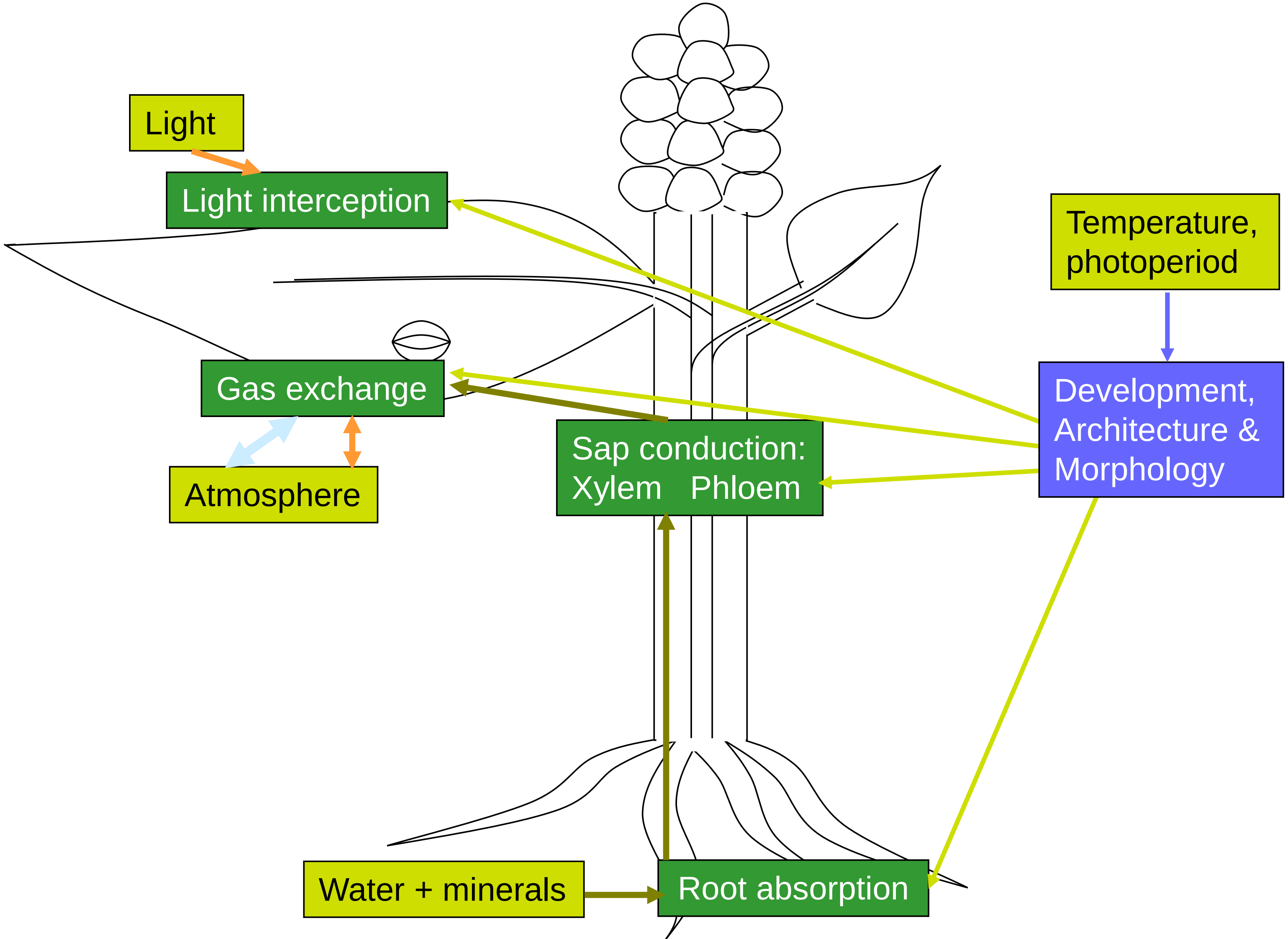
Modelling


Light
Temperature, photoperiod
Atmosphere
Water + minerals

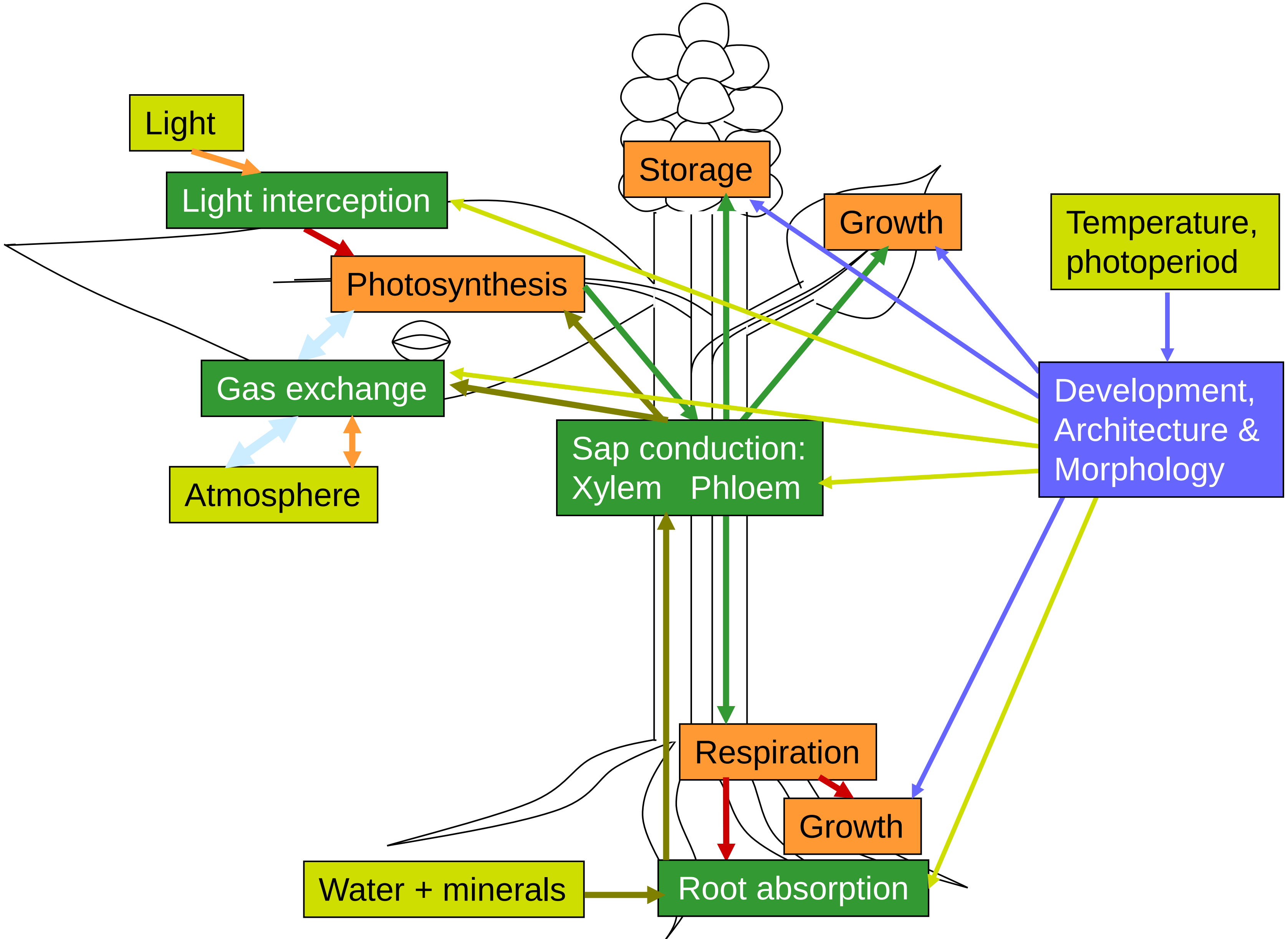
Modelling


Light
Atmosphere
Water + minerals
Temperature, photoperiod
Development, Architecture & Morphology

Modelling


Light
Light interception
Gas exchange
Atmosphere
Sap conduction:
Xylem Phloem
Temperature,
photoperiod
Development,
Architecture &
Morphology
Water + minerals
Root absorption

Modelling



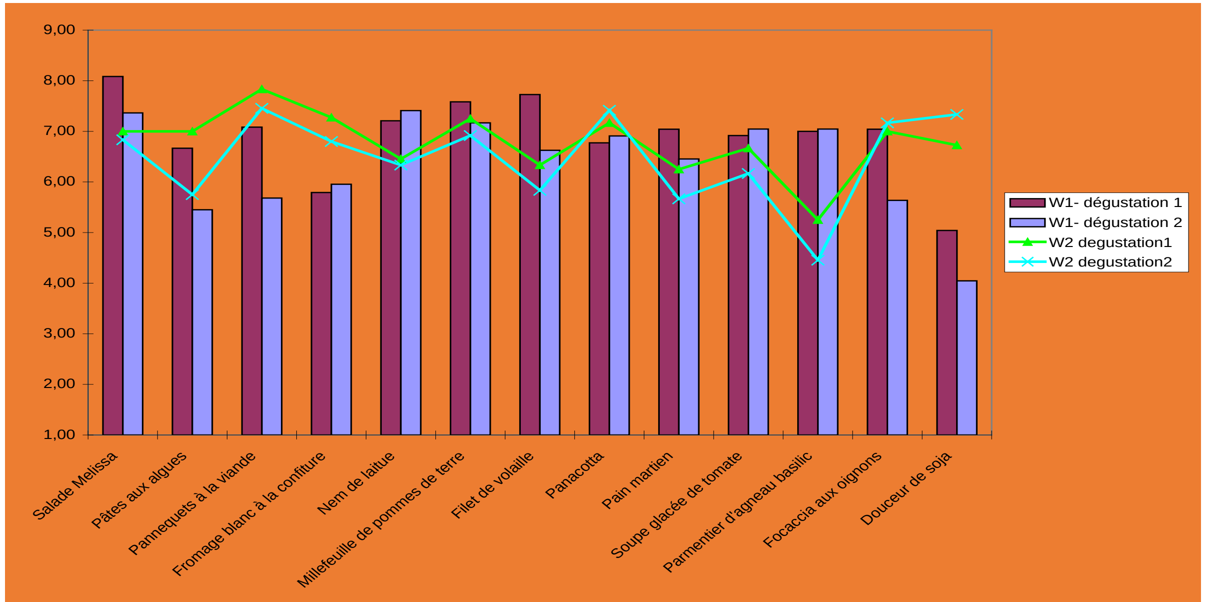
Light
Light interception
Photosynthesis
Gas exchange
Atmosphere
Storage
Growth
Temperature, photoperiod
Development, Architecture & Morphology
Sap conduction: Xylem Phloem
Respiration
Growth
Water + minerals
Root absorption





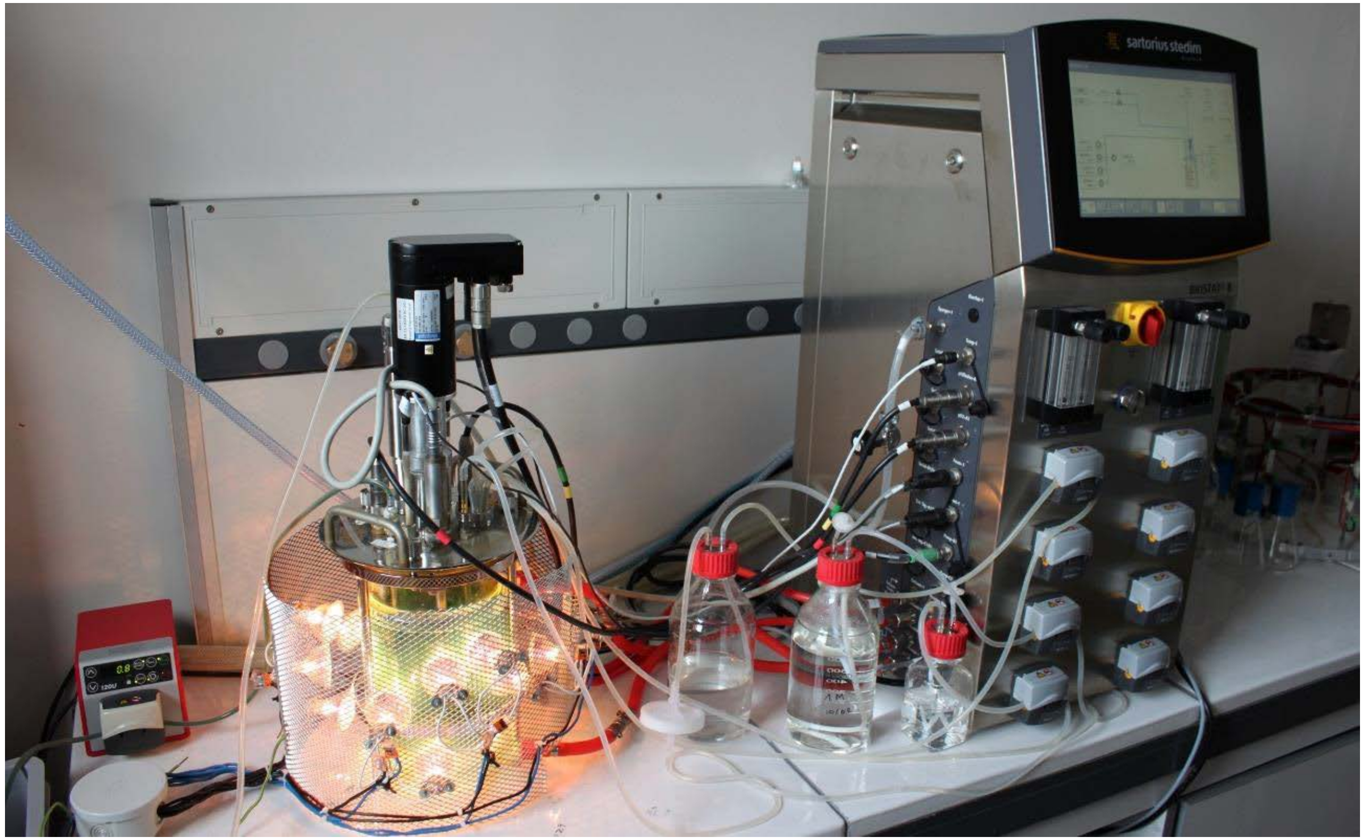
Participation in Bedrest

- ✓24 subjects (women).
- ✓3 groups: Controls – ***Exercise* – *Nutrition.***
- ✓Duration: 106 days for each successive period

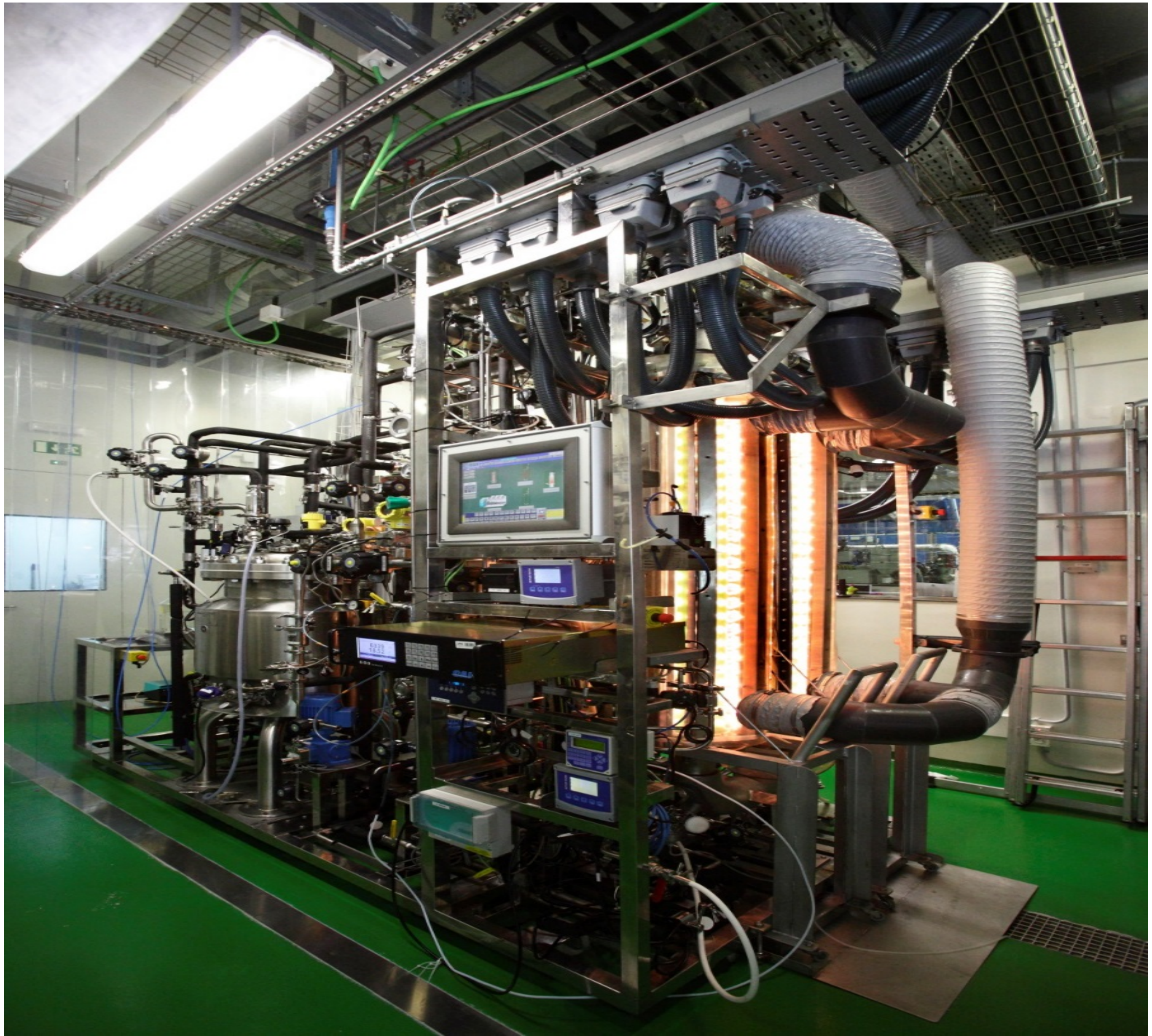


From Bench Scale to Flight Hardware

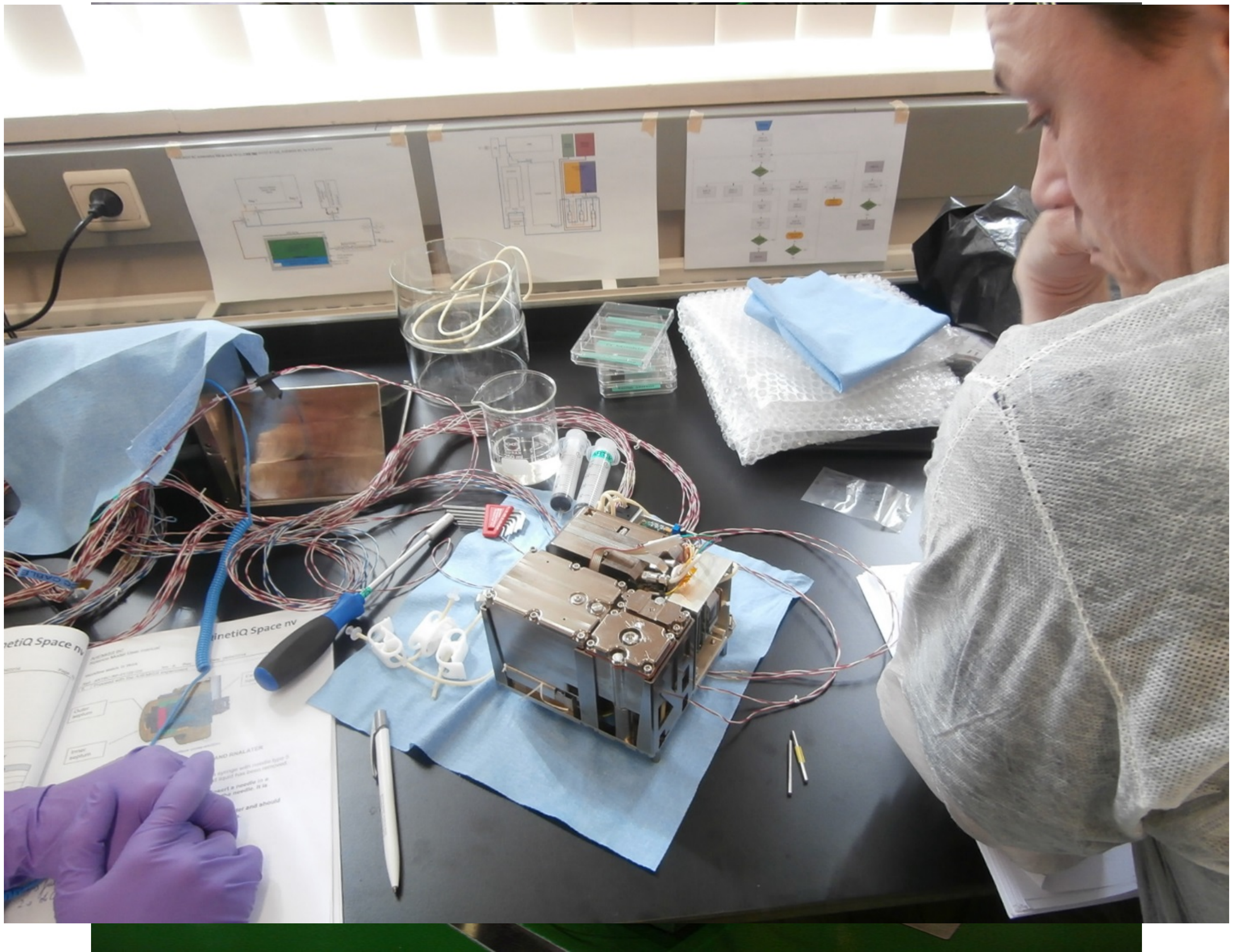
Scale Up, then Down, then Up



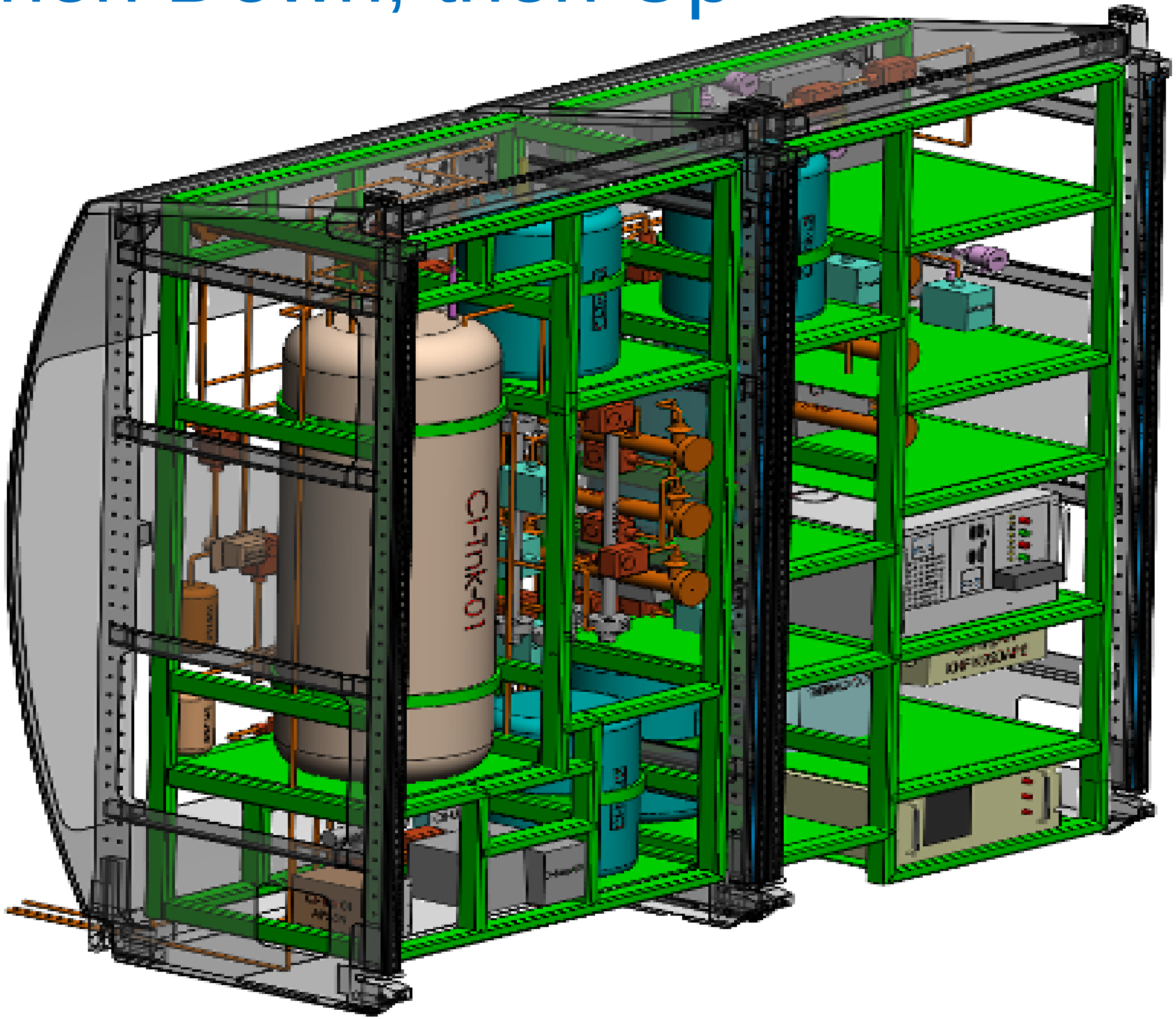
Scale Up, then Down, then Up



Scale Up, then Down, then Up

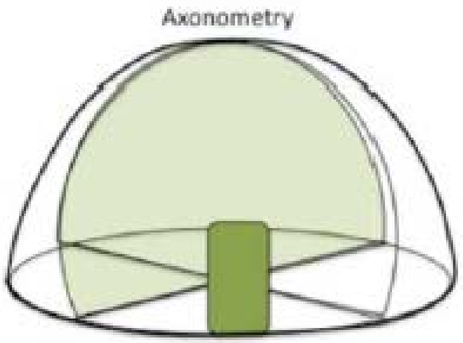


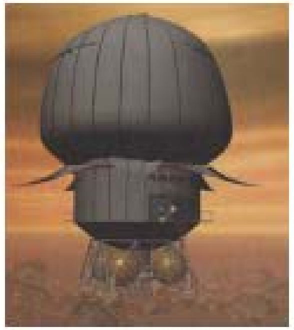
Scale Up, then Down, then Up



PS selected concepts for further analysis

1 – INFLATABLE DOME – ONE MEMBRANE

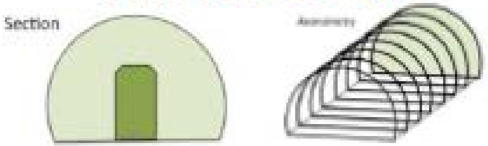




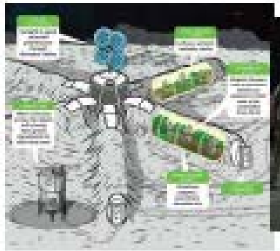
SICSA MarsLab Concept [2004]

SICSA LunarHab Concept [1980]

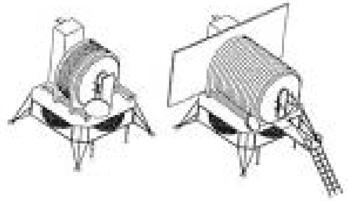
2 – INFLATABLE CYLINDER W. INT. STRUCTURE



LGH Arizona University [on-going]

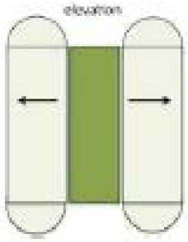


NASA/ILC Lunar Habitat [1996]

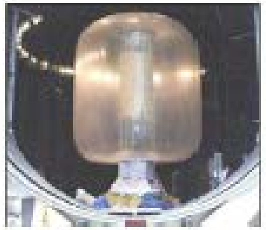


TASI/Aero Sekur STEPS2 [on-going]

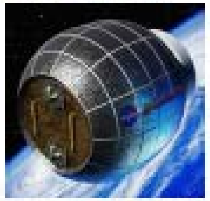
3 – INFLATABLE CYLINDER W. INT. RIGID CORE



NASA/ILC Dover/TASI TransHab [2000]



NASA/Bigelow Genesis I, II and BEAM [on-going]



ESA/TASI/ Aero Sekur IMOD [2006]

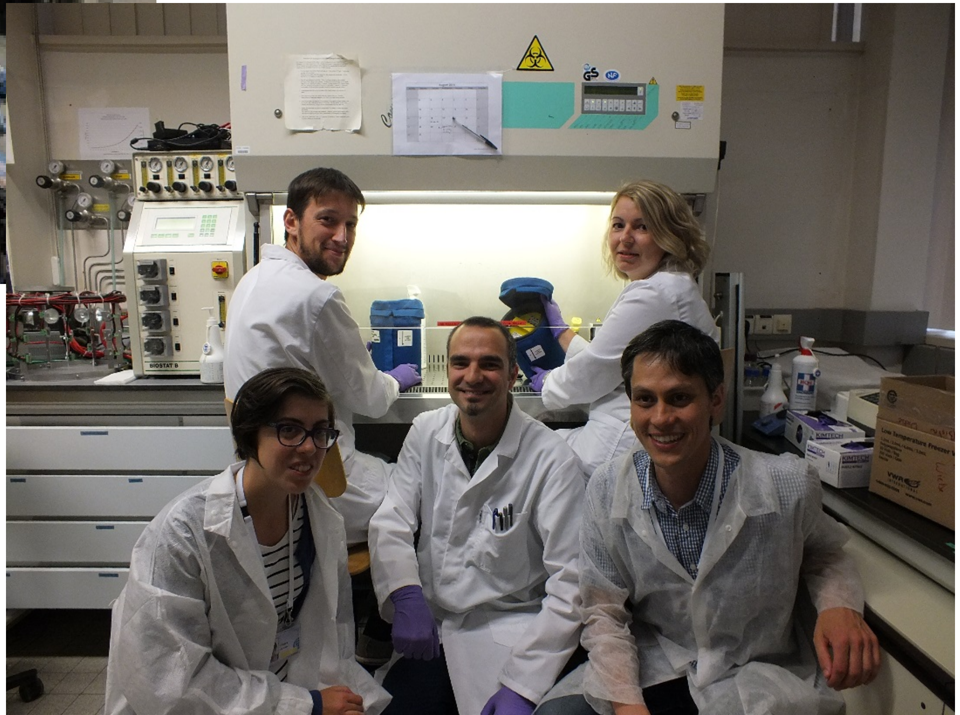

MELISSA
ThalesAlenia Space
esa
LAB and STORAGE
Rigid-Flex
ThalesAlenia Space

Access to Space

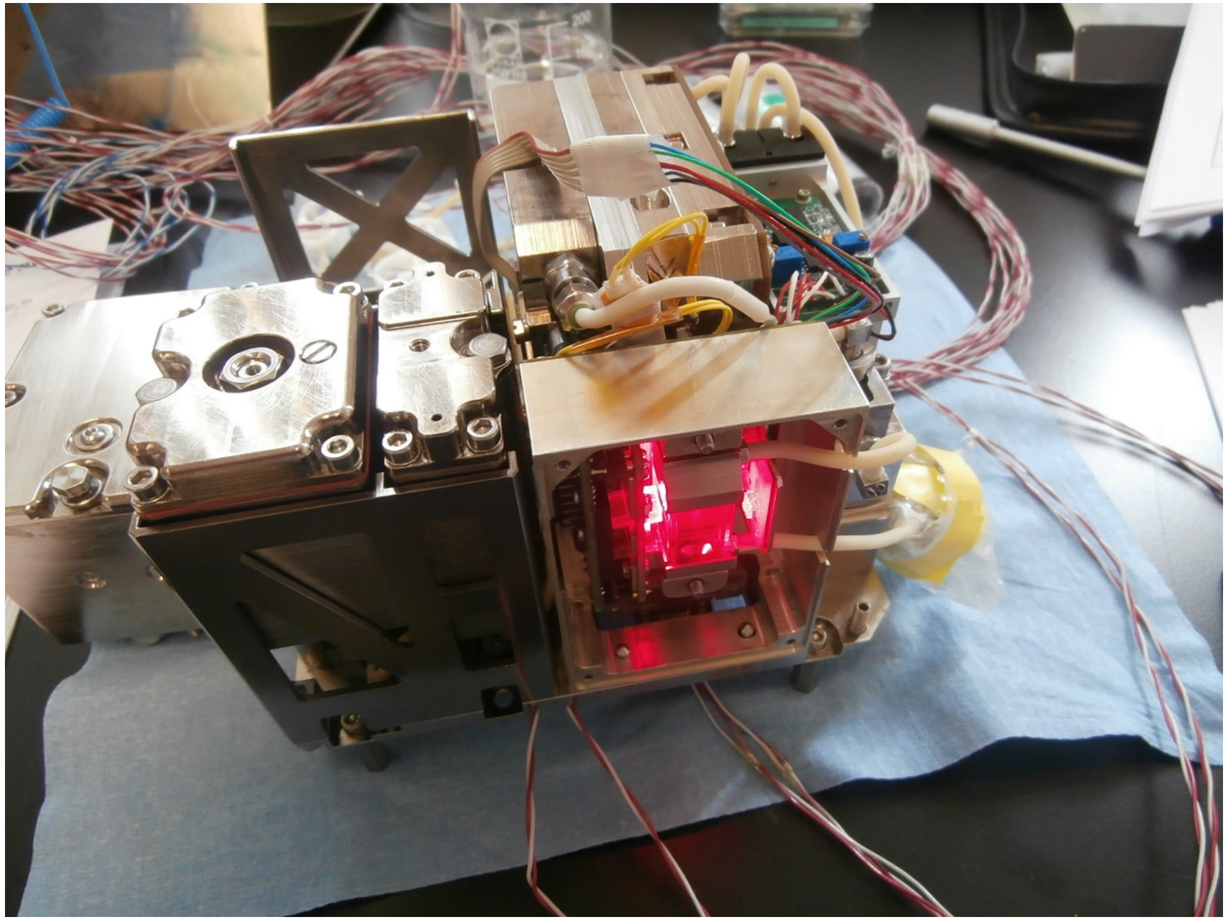
MELISSA Space Flight Experiments

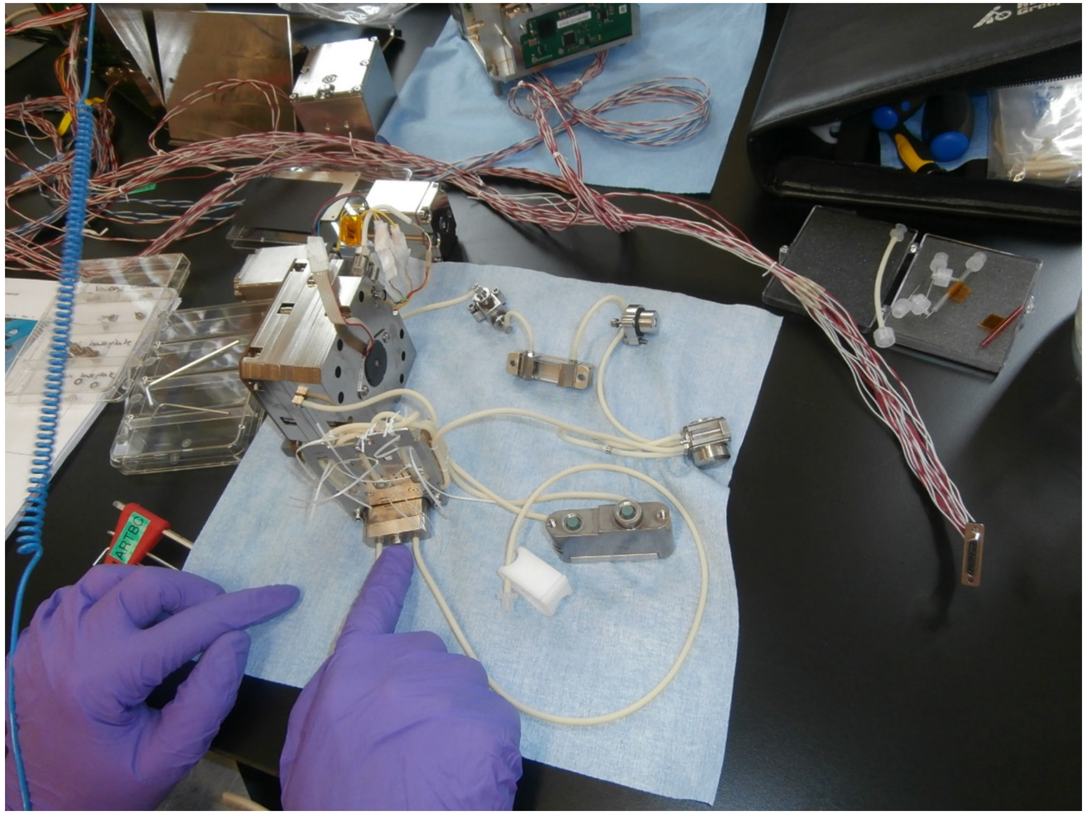
- **MESSAGE 1** (ISS)(2002)
- **MESSAGE 2 (**ISS)((2003)
- **MOBILIZATION 1 (**ISS)((2004)
- **BASE A (**ISS)**(**2006)
- **BASE B& C** (ISS)(2008)
- **Nitrimel** (FOTON)(2014)
- **MELONDEAU, incl BISTRO** (ISS)(2015)
- **ArtEMISS-B/Arthrospira-B** (ISS)(2017?)
- ARTEMISS-C/Arthrospira-C (ISS)((?)
- URINIS (ISS)(?)
- BIORAT-1
- ...

The last one: BISTRO



The Next One: ARTEMISS





Access to Earth

CURRENT PROJECTS

Biobased and *circular* economic models in the following sectors:

Agro & Food

Life sciences & Health

Water & Waste

examples

MELiSSA BIOSTYR®

BIOSTYR®

- water treatment plants across Europe apply BIOSTYR® technology to treat waste water
- Developed by MELiSSA and marketed by Veolia
- hundreds of millions of liters of water are treated each year

examples

Kinetra, Morocco

Water treatment plant

- Treatment of highly polluted ground water
- Capacity: 1200 people
- Output: safe potable water
- Low energy consumption

Koningshoeven Abbey - Brewery

Partners:
- Koningshoeven Abbey La Trappe
- Water Board De Dommel
- IPStar / UGent
- BioPolus

Objectives
- Create circular La Trappe Brewery
- Treat Water brewery & household
- initiate experiments

Phasyn project

Bioplastic development

Umons – MaterinaNova

- Production of PHAs from fermentation by-product (waste water)
- PHAs production modelling
- PHAs best composition evaluation
- PHAs composition tuning
- PHAs processability, physico-chemical properties
- PHAs additivation

Alpo Project

New biotimulant for plant defense

Umons - MateriaNova Greenwin

- Specific Arthrospira compound as biostimulant - defense of plants
- Patent
- Foliar spray or soil amendment
- Synergic effect with major commercial product
- Tested in real situation (Industrial Partners)

plant **biostimulant**

PROJECTS

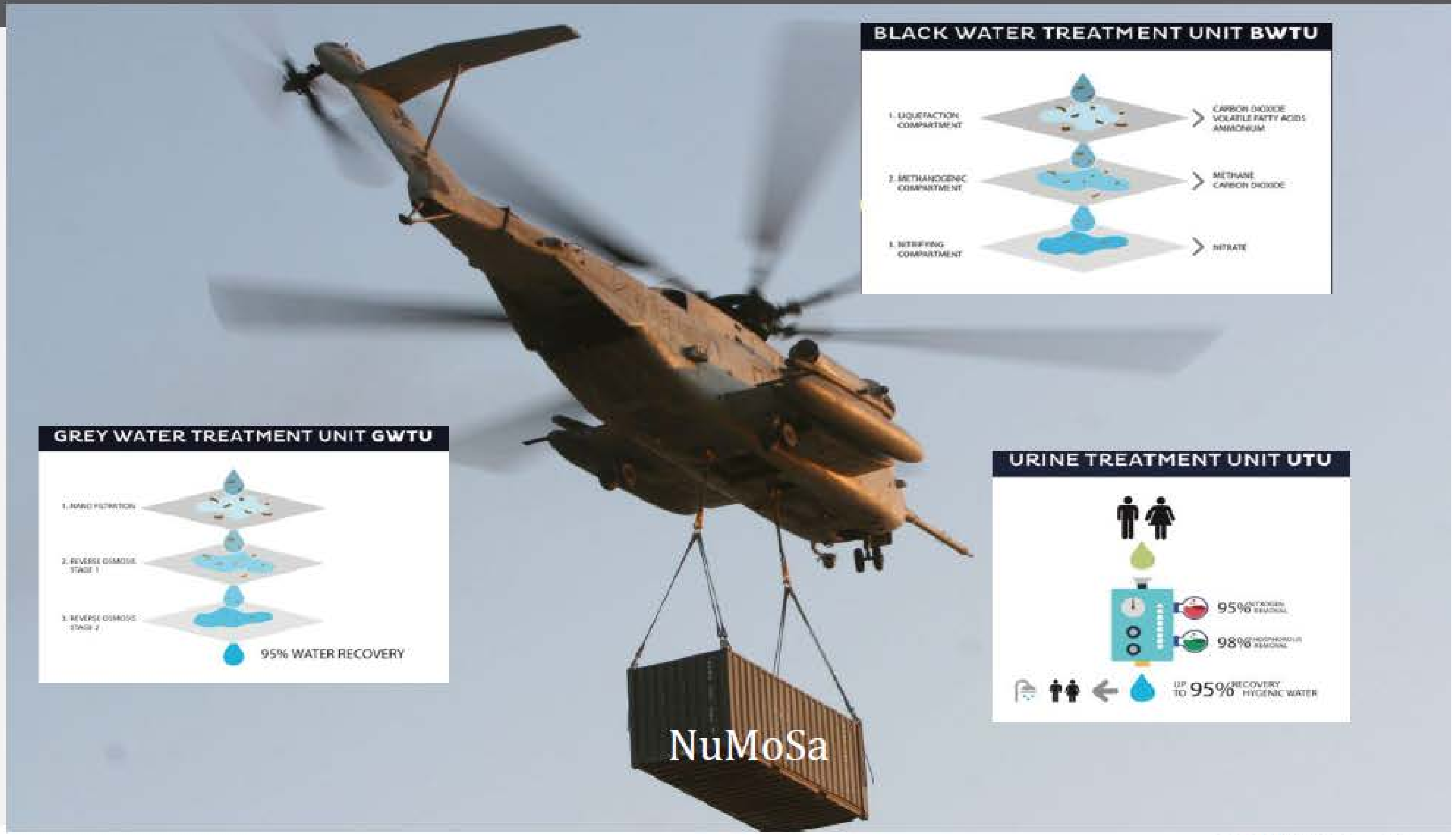
SEMiLLA Sanitation Hubs

Mobile sanitation unit:

- sanitation, safe water and essential foods
- Refugee camps
- Residential applications

Partners:

- HAS University of Applied Sciences
- UGent
- IPStar BV



examples

algosolis: an R&D facility dedicated to the development of sustainable microalgae industry

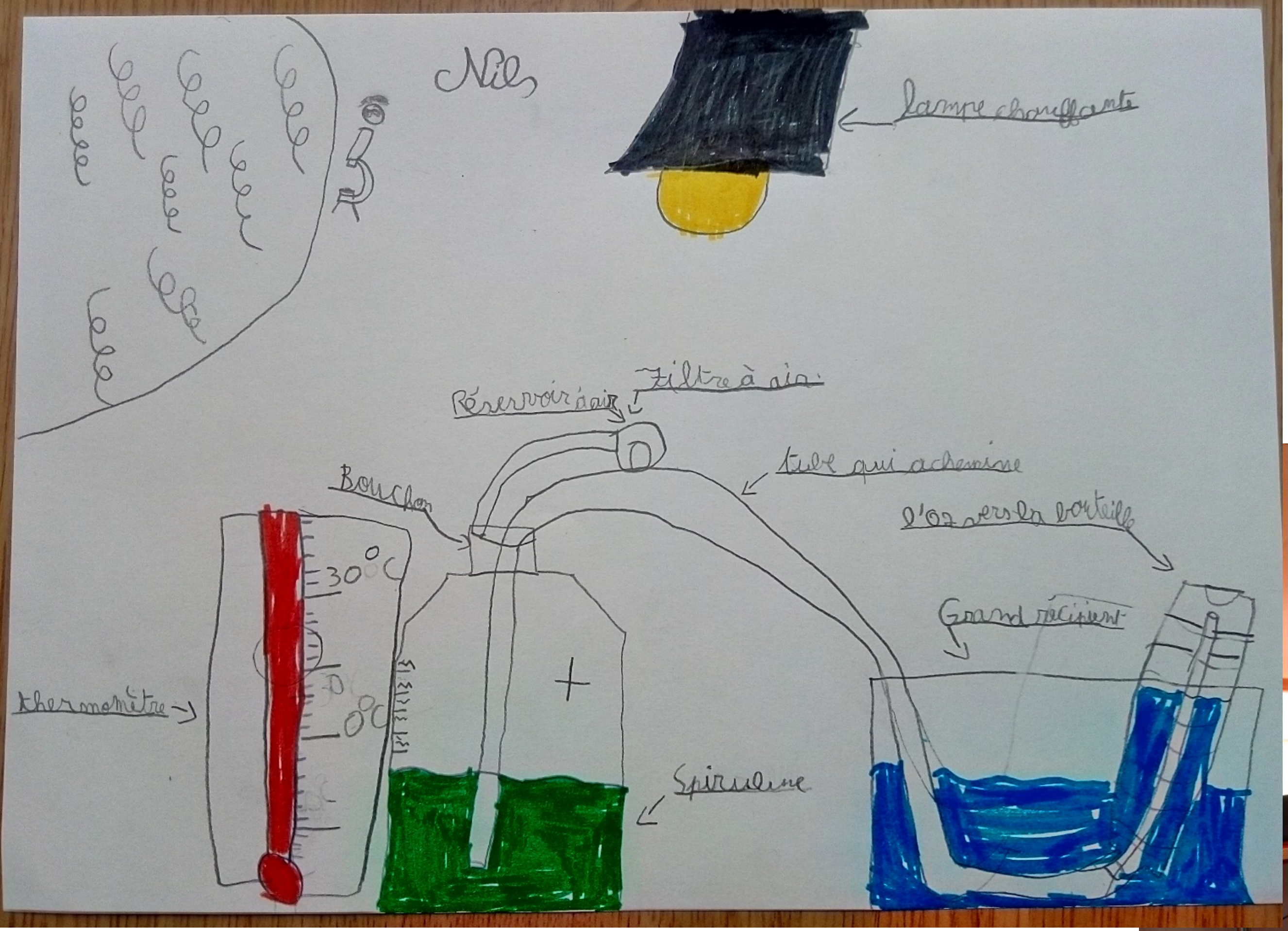
Breakthrough technologies for microalgae culture and algorefinery

Preparing for the Future….

MELiSSA as a tool to promote STEM to youngsters ...

e.g. **'Food from Spirulina'** (2015)

- 1000 experiment kits for teachers & students (12-14 j)
- Inflight call to Samantha Cristofferetti in ISS


Nils
lampe chauffante
Filtre à air
Réservoir à air
Bouchon
tube qui achemine
l'O2 vers la bouteille
Grand récipient
Spiruline
thermomètre
30°C


vous
Club Monge Emeraude
Cercle Poincaré Or
Cercle Poincaré Argent
Cercle Poincaré Bronze
Club Monge Saphir
Cercle Poincaré Or
Cercle Poincaré Bronze

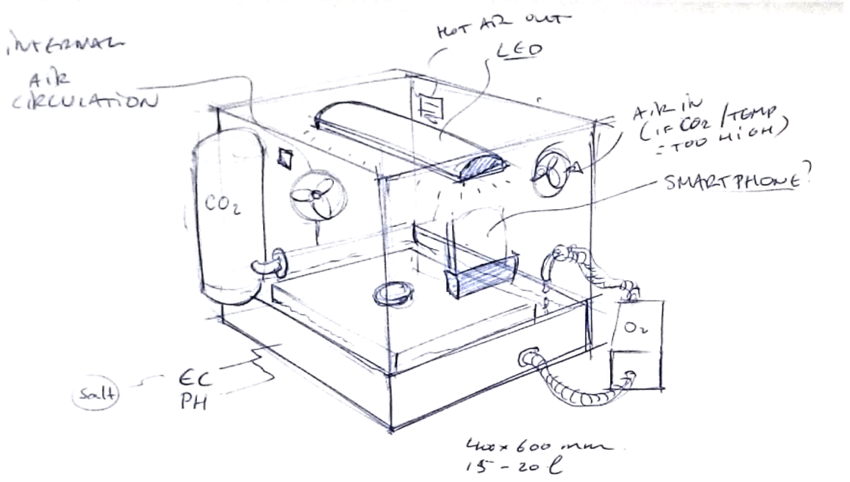

GHENT UNIVERSITY
200 JAAR
UNIVERSITEIT GENT
FACULTY OF BIOSCIENCE ENGINEERING

Citizen Science

- What?
  - Education project for students (14-18 years) based on plant growth observation and scientific data acquisition
  - Design and construction of education kit (WatchMeGrow kit) to be distributed in schools
- How?
  - Design Co-creation with a group of experts (Hackathon)
  - Prototype production in Fab-Lab (Hackathon)
  - Testing and validation in selected schools
  - Final WatchMeGrow production and distribution
- When?
  - Hackathon 7/8 April 2017
- Where?

  BlueCity (centre for circular economy),

  Rotterdam, Netherlands



Conclusion

- MELiSSA is an European project aiming to gain knowledge and demonstrators of circular system,
- MELiSSA is open to European collaborations,
- After 28 years, the challenges are still very high and it is a very long term effort,
- Terrestrial interest is clearer everyday, and we aim to contribute to the circular economy challenges, including via Education.

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