MELiSSA Pilot Plant: Developing Life Support Technology for Human Space Exploration

MELiSSA Pilot Plant – Claude Chipaux Laboratory
Universitat Autònoma de Barcelona - European Space Agency

First Lego League 2018.

Escola Politècnica Superior. Universitat de Lleida. 27.11.18

Current International Planning

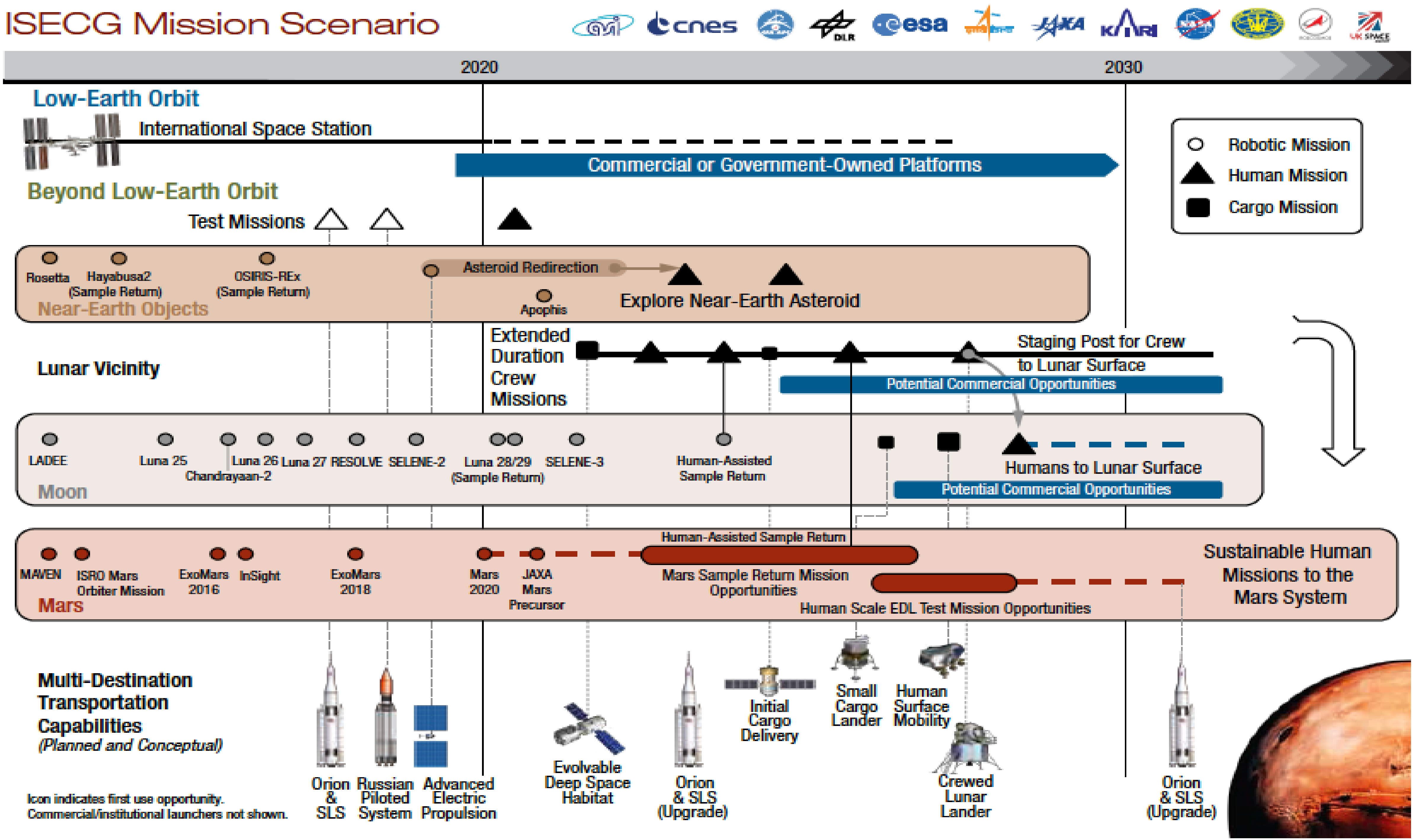
Using the International Space Station
Missions: 6-12 months
Return: Hours
~400 km/250 miles

Operating in the Lunar Vicinity
Missions: 1-12 months
Return: Days
~380,000 km/240,000 miles

Leaving the Earth-Moon System
Missions: 2-3 years
Return: Months
~220 million km/140 million miles

Reaching the Mars Surface
One year stay
Limited return opportunities
Autonomy required
Utilize local resources
Mobility for Science

A step-wise journey from the safety of Earth's orbit, to the vicinity of the Moon and then into the Solar System


ISECG Mission Scenario
2020
2030
Low-Earth Orbit
International Space Station
Commercial or Government-Owned Platforms
Beyond Low-Earth Orbit
Test Missions
Robotic Mission
Human Mission
Cargo Mission
Rosetta
Hayabusa2 (Sample Return)
OSIRIS-REx (Sample Return)
Asteroid Redirection
Apophis
Explore Near-Earth Asteroid
Near-Earth Objects
Extended Duration Crew Missions
Staging Post for Crew to Lunar Surface
Lunar Vicinity
Potential Commercial Opportunities
LADEE
Luna 25
Chandrayaan-2
Luna 26
Luna 27
RESOLVE
SELENE-2
Luna 28/29 (Sample Return)
SELENE-3
Human-Assisted Sample Return
Humans to Lunar Surface
Potential Commercial Opportunities
Moon
MAVEN
ISRO Mars Orbiter Mission
ExoMars 2016
InSight
ExoMars 2018
Mars 2020
JAXA Mars Precursor
Human-Assisted Sample Return
Mars Sample Return Mission Opportunities
Human Scale EDL Test Mission Opportunities
Sustainable Human Missions to the Mars System
Mars
Multi-Destination Transportation Capabilities
(Planned and Conceptual)
Orion & SLS
Russian Piloted System
Advanced Electric Propulsion
Evolvable Deep Space Habitat
Orion & SLS (Upgrade)
Initial Cargo Delivery
Small Cargo Lander
Human Surface Mobility
Crewed Lunar Lander
Orion & SLS (Upgrade)
Icon indicates first use opportunity.
Commercial/institutional launchers not shown.

Main requirements for Human Space Exploration and life support systems.

Human Space Eploration main challenges

- Safety and protection for the crew. Radiation
- Advanced Propulsion. Reduction of mission time
- Lifef support. Make the mission posssible
  - Air revitalization
  - Water reutilization
  - Waste management
  - Food production and preparation

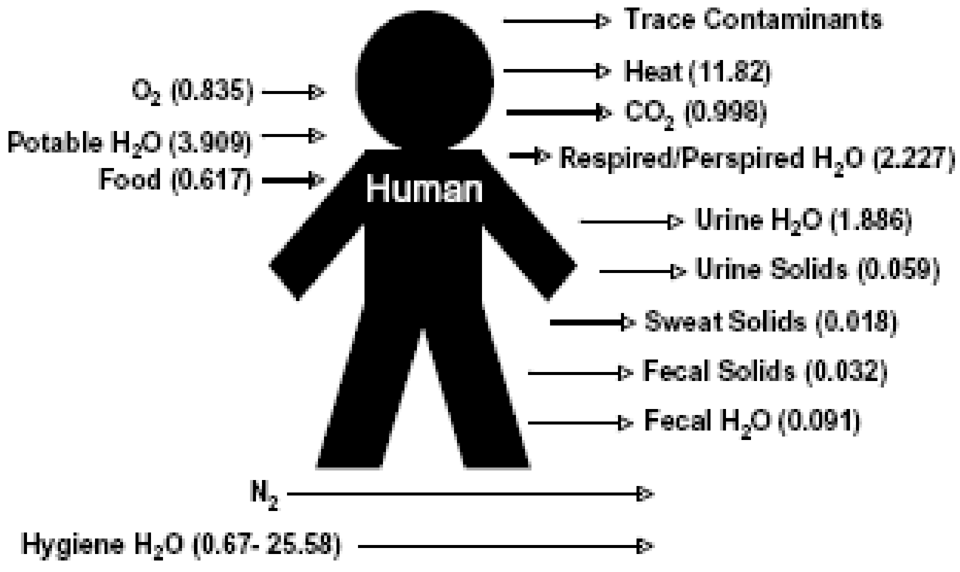


Figure 1. Human Consumable and Throughput Values in kg (or MJ)/crewmember/day

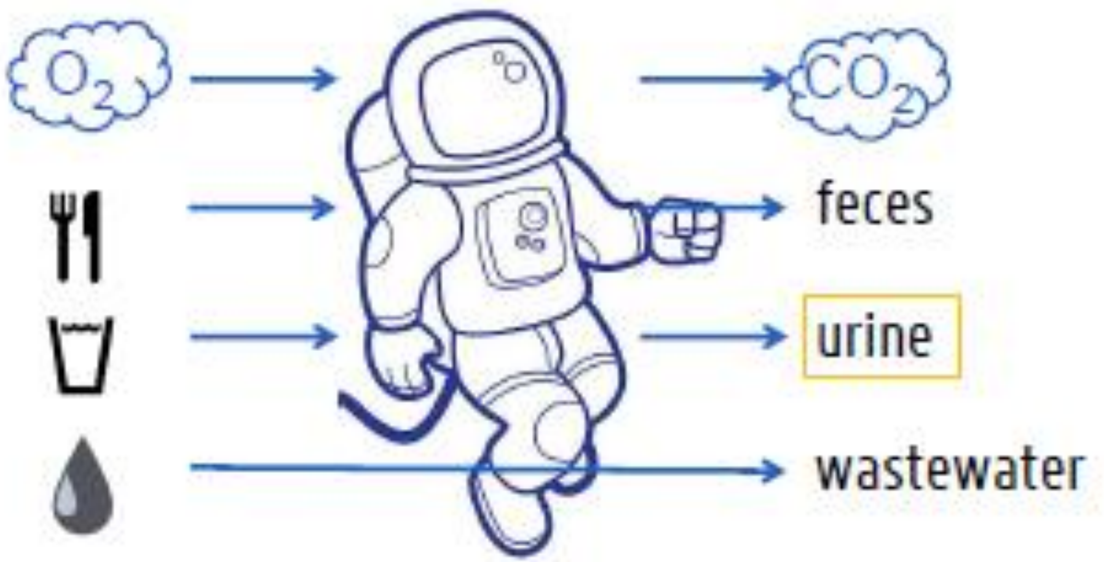
STATE-OF-THE-ART TECHNOLOGY INTERNATIONAL SPACE STATION

ISS025E007248

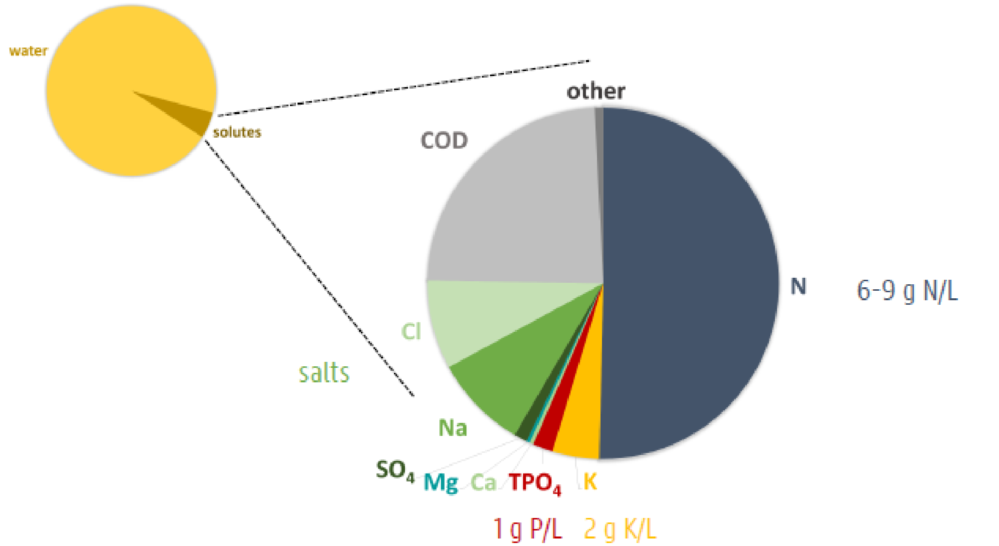
Water Recovery and Managemen
NASA (www.nasa.gov)

- water recovery and management system
- urine, condensate and Sabatier water
- physical-chemical processes (VCD, filtration)
- potable water

URINE, AN IMPORTANT WATER RECOVERY TARGET IN A RLSS



URINE IS RICH IN NUTRIENTS



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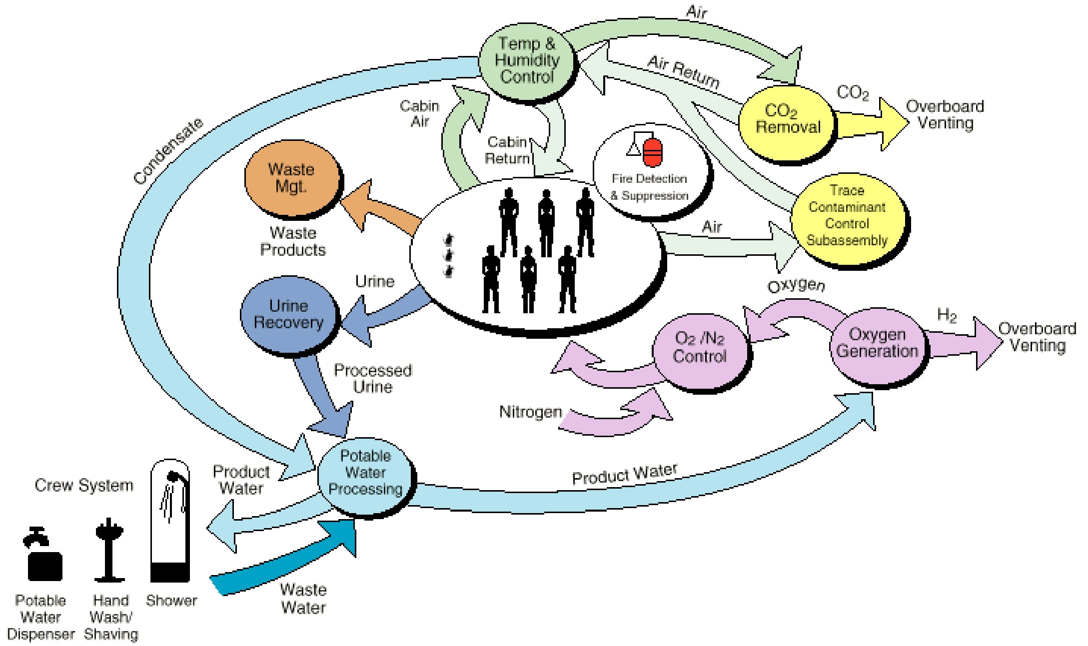
The International Space Station toilet. NASA (www.nasa.gov)

Environmental Control and Life support in ISS and beyond

ISS current life support and environmental control

Open system. No food generation or waste treatment. Supply from Earth

- O_2 generation
- CO_2 capture
- Water reclamation
- Trace contaminants control



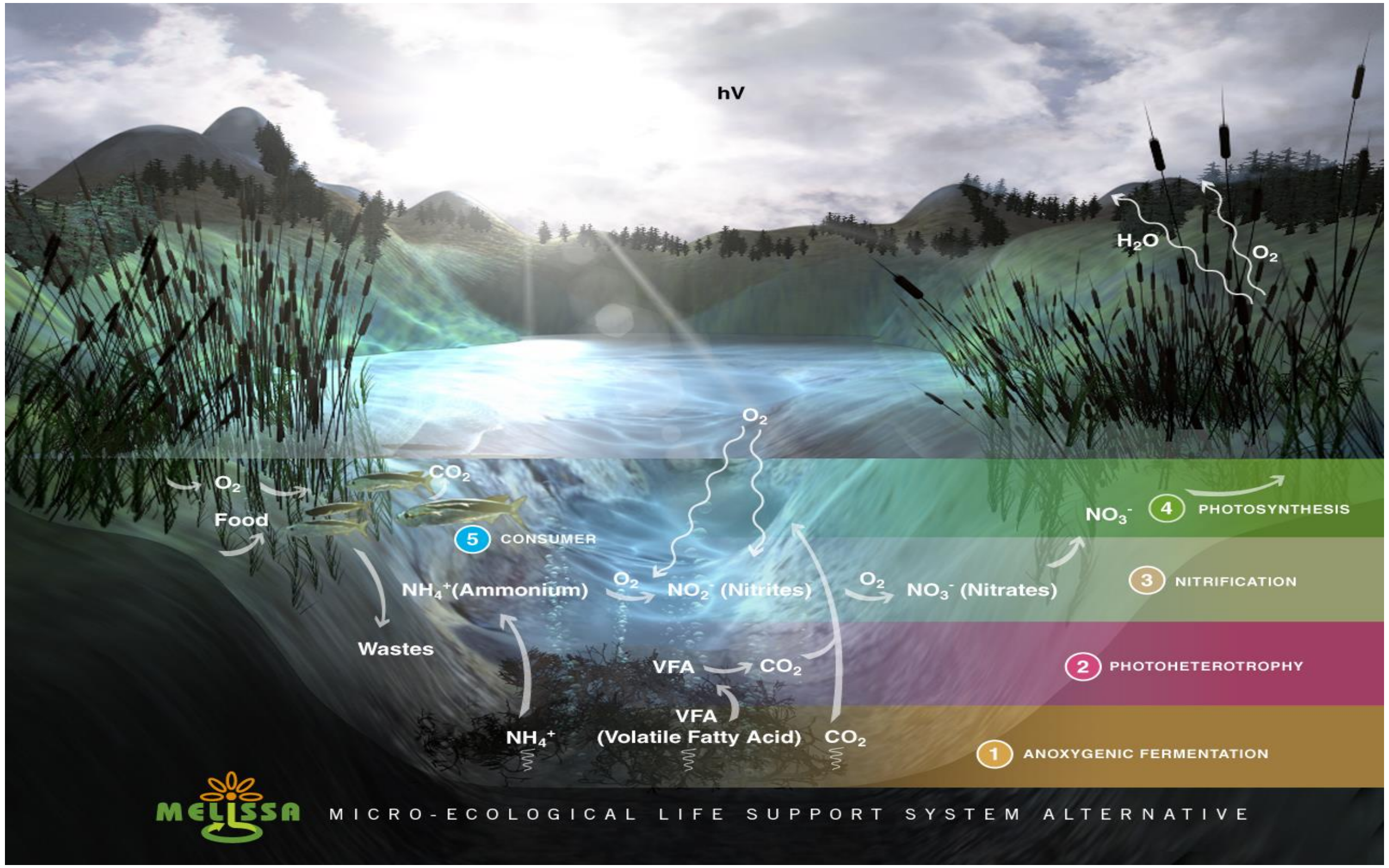
Metabolic consumables: 5 kg/day/person, 6 crew members, 1000 days (Mars mission): 30.000 kg

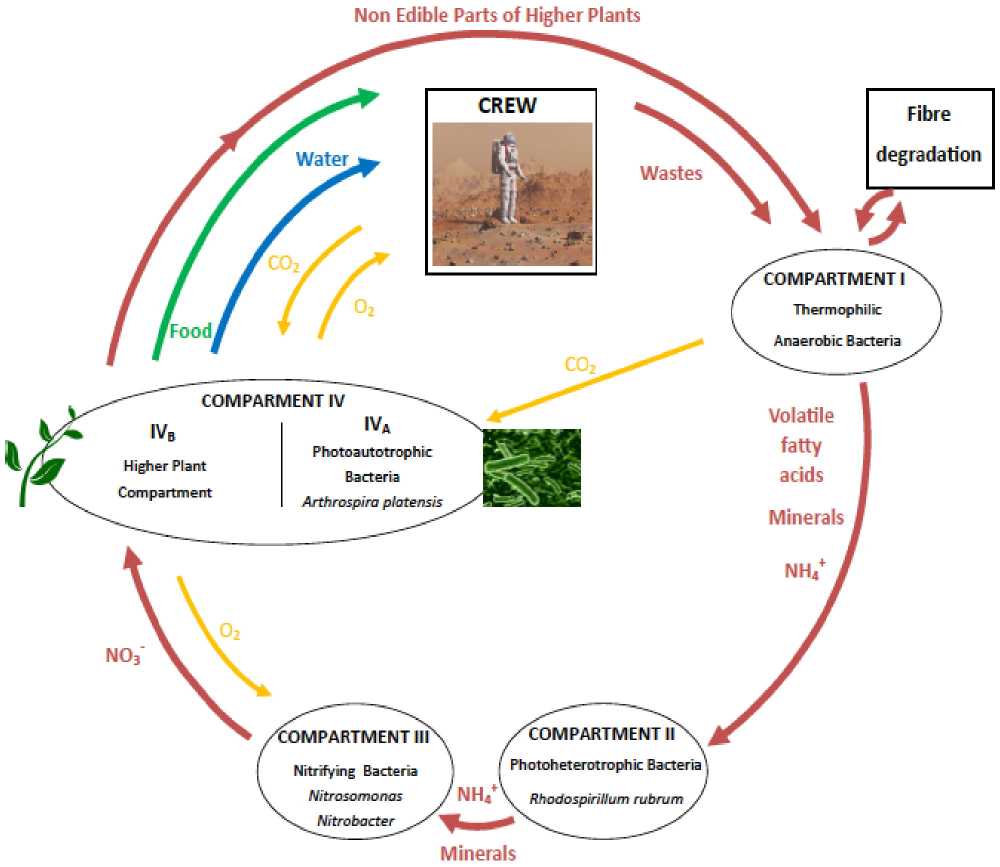
Including hygiene issues (20 kg/day/person): 132.000 kg

This is a too high mass for a mission … **long-term missions need regenerative LSS**

The MELiSSA Concept: engineering a closed ecosystem

MELiSSA approach is to perform the most relevant biological functions of an ecosystem in individual compartments (bioreactors and higher plant chambers), in continuous and controlled operation





The MELiSSA Pilot Plant: technology demonstration and integration

esa
UAB Universitat Autònoma de Barcelona
MELiSSA

Main objectives

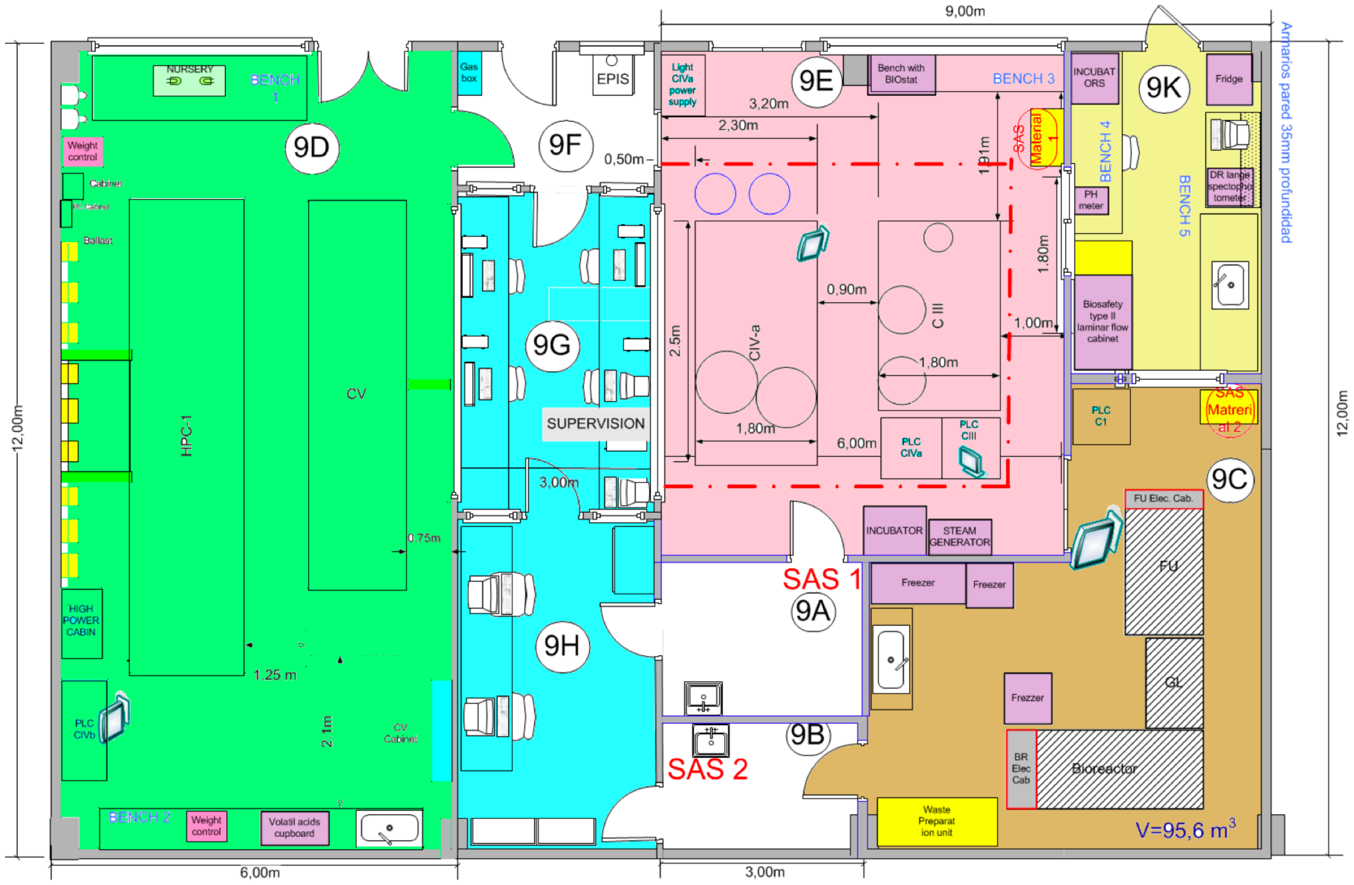
Integration and demonstration of the MELiSSA concept at pilot scale

Technology demonstration:

- In ground conditions
- With an animal crew
- With industry standards
- Long-term continuous operation
- Modelling and Control

Production of Oxygen: equivalent to one person respiration
Production of food: 20-40 % of a person requirements

Layout (214 m^2)



Comp. IVb and CV

Comp. III and IVa

Control and supervision

Comp I

Analysis Laboratory

The MELiSSA Pilot Plant (MPP)

COMPARTMENT | I | II | III | IVa | IVb | V

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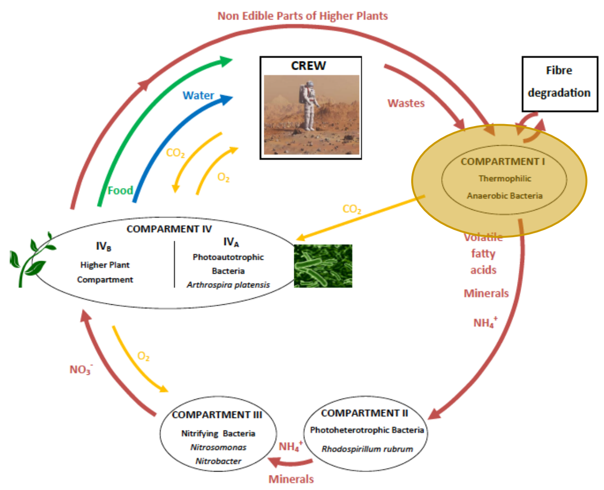
Function in the loop

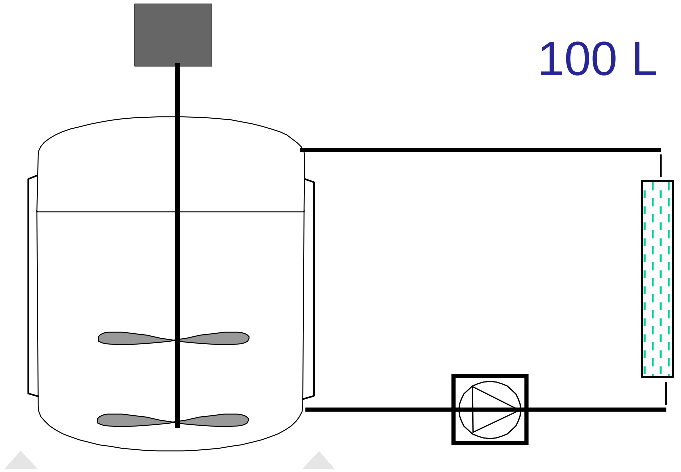
Wastes → C. I → Volatile Fatty Acids (VFA) CO_2



Biological component

Mixed culture of thermophilic anaerobic bacteria

Technology



Waste Preparation Unit (WPU). Raw materials

- Plant material (lettuce, wheat straw, beet)
- Toilet paper
- Human faeces

EPAS ECO PROCESS ASSISTANCE

The MELiSSA Pilot Plant (MPP)

COMPARTMENT | I | II | **III** | IVa | IVb | V

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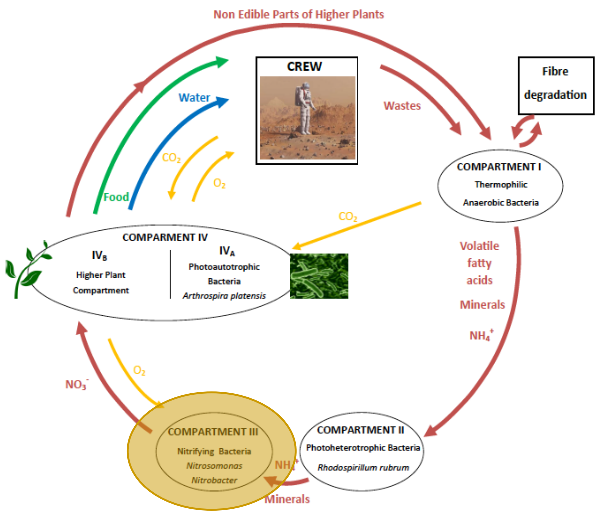
Function in the loop

NH_4^+
O_2 → **C. III** → NO_3^-



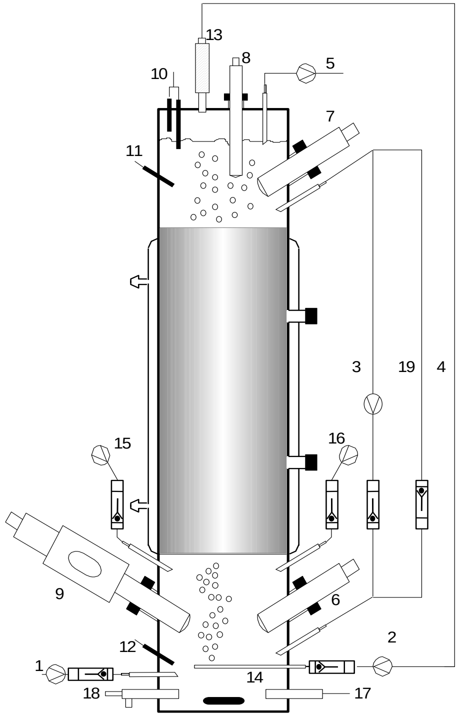
Biological component

Nitrosomonas europaea
Nitrobacter winogradskyi
(Axenic co-culture, aerobic)

Technology

7 L

BIOPROCESS TECHNOLOGY · SNC·LAVALIN

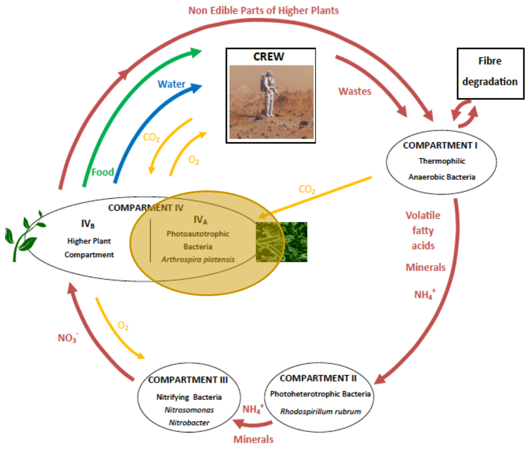


The MELiSSA Pilot Plant (MPP)

COMPARTMENT | I | II | III | **IVa** | IVb | V

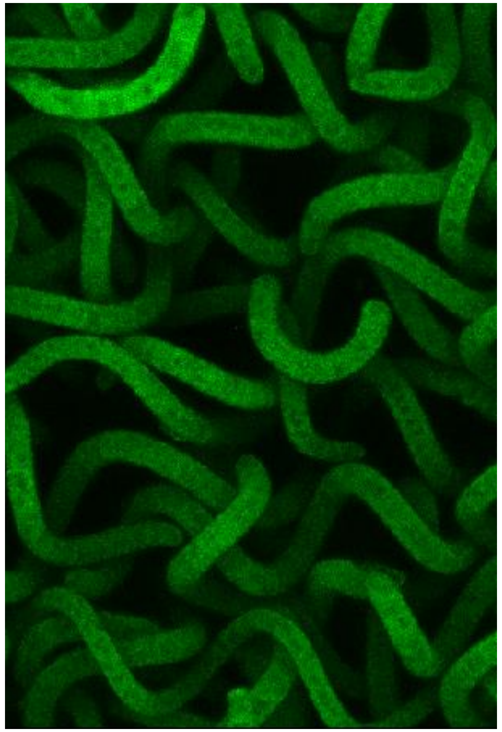
Function in the loop

Light
CO_2
→ **C. IVa** →
Biomass
O_2



Biological component

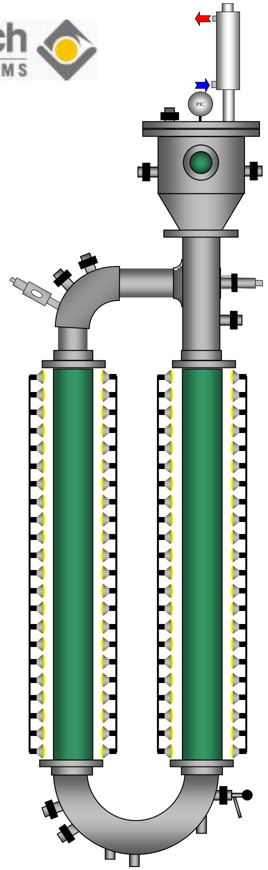
Arthrospira platensis
(axenic culture)



Technology

83 L

De Dietrich PROCESS SYSTEMS



The MELiSSA Pilot Plant (MPP)

COMPARTMENT	I	II	III	IVa	**IVb**	V

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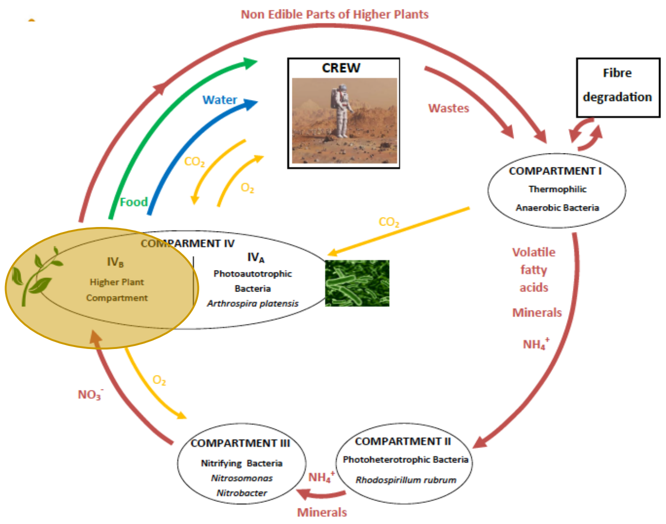
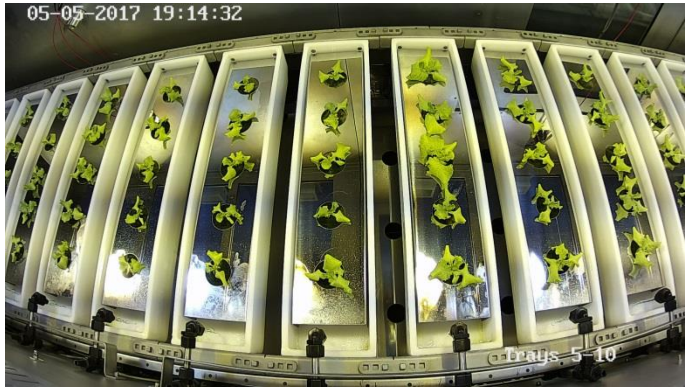
Function in the loop

Light
CO_2 → **C. IVb** → **Biomass**
O_2



Biological component

Higher plants
(letuce, beat,wheat)



Technology

UNIVERSITY of GUELPH Amstrong Engineering

The MELiSSA Pilot Plant (MPP)

COMPARTMENT	I	II	III	IVa	IVb	V

Function in the loop

O_2
Feed

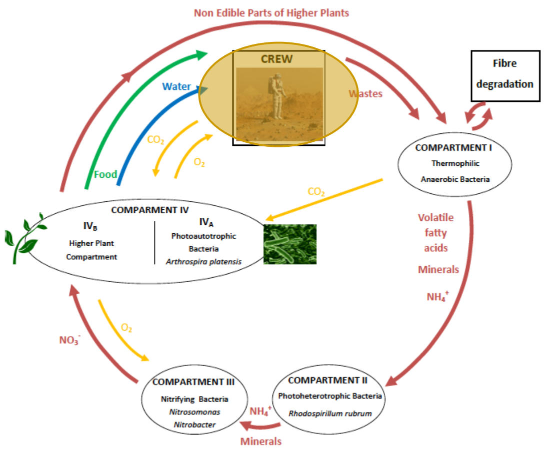
C. V

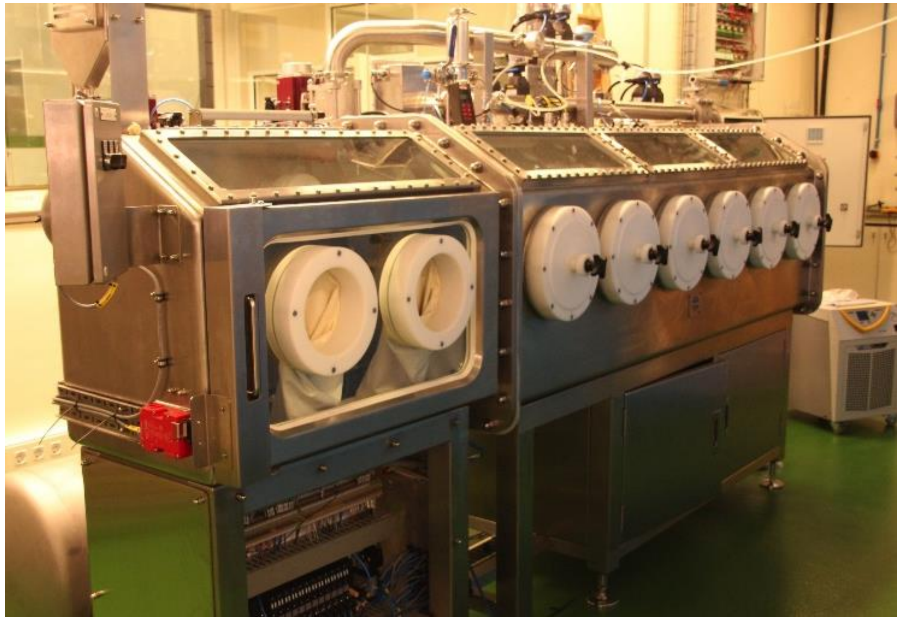
Wastes
CO_2

Biological component

Laboratory Wistar rats

Technology





Integration Strategy: C. III / C. IVa / C. V

Top requirements for the MELiSSA Pilot Plant

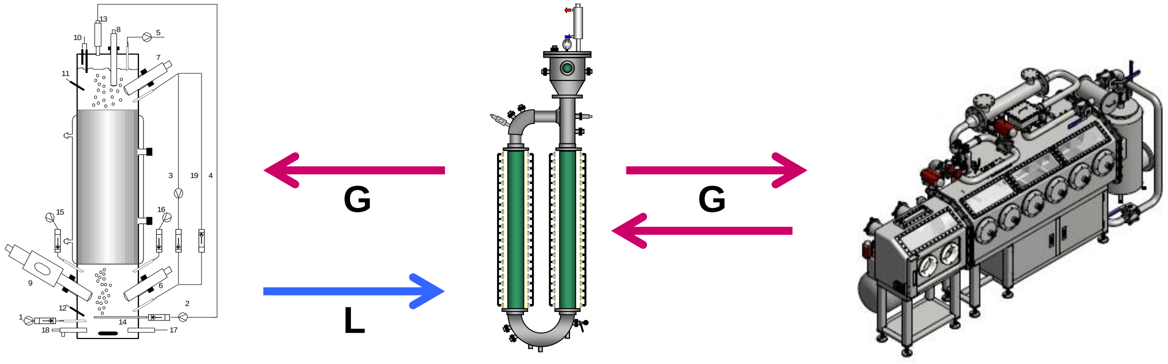
1/ Progressive demonstration of MELiSSA concept

2/ Stepwise integration

3/ Capitalization of knowledge

First integration steps based on the most advanced compartments in terms of knowledge, model and control

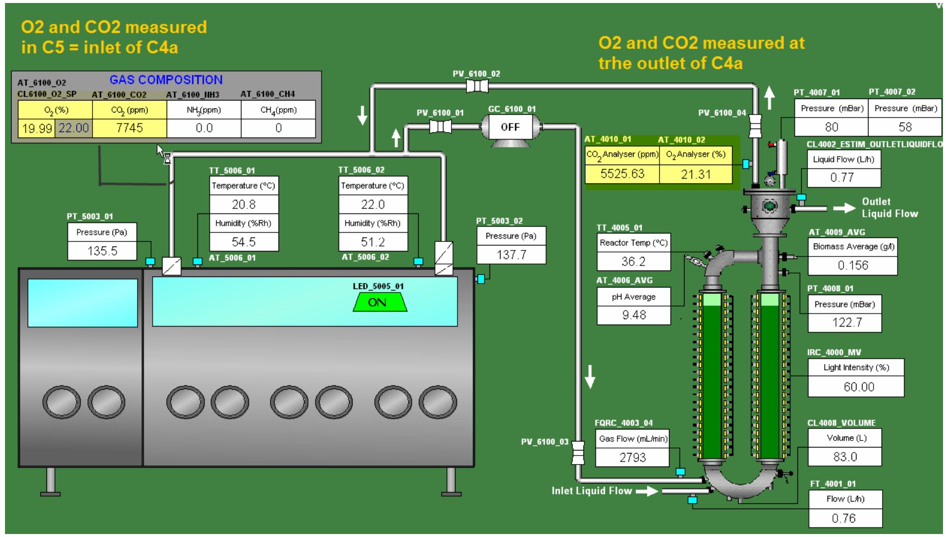
Integration WP1 **Integration WP3** **Integration WP4** **Integration WP6**

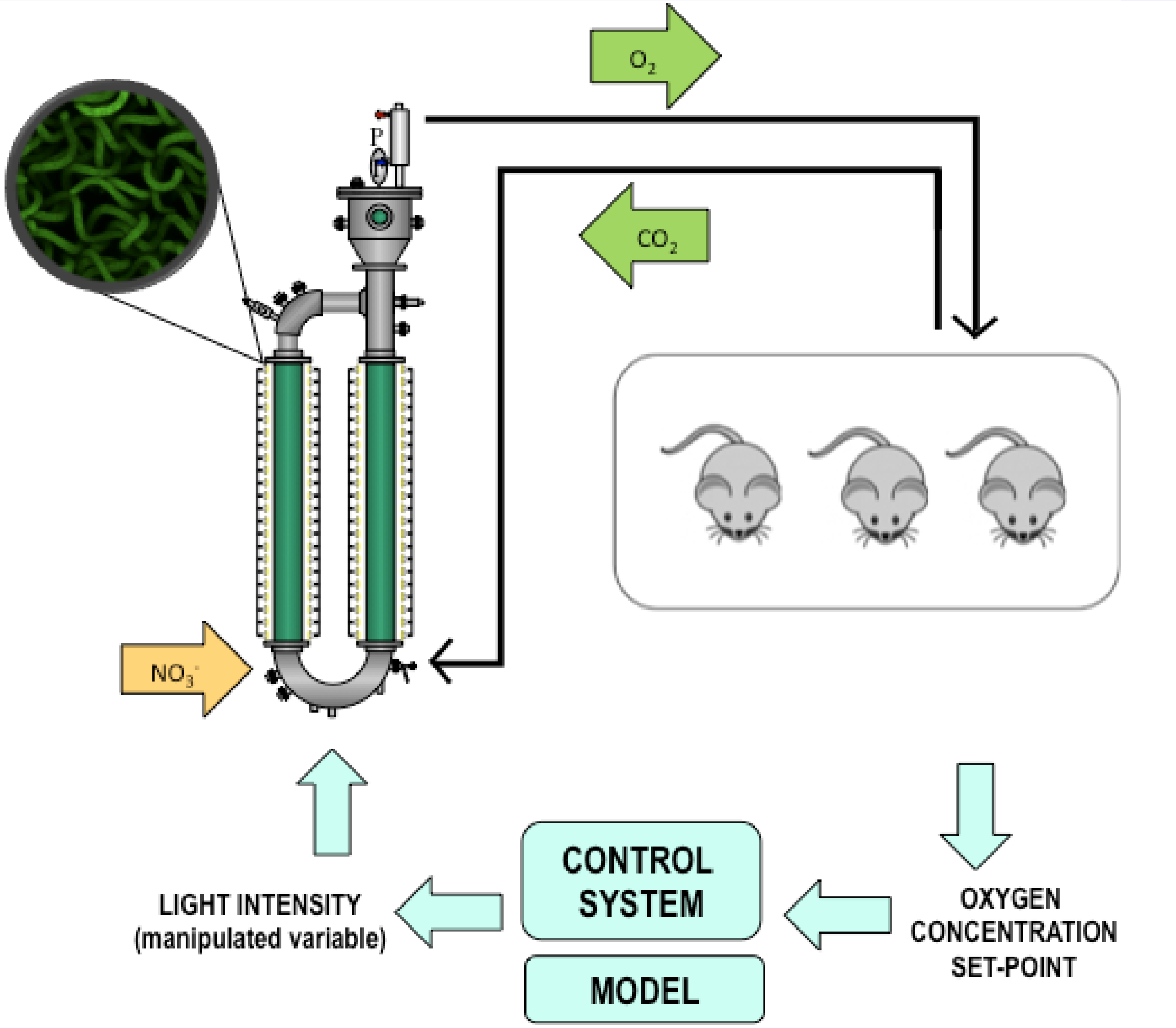


WP1 integration. CIVa + CV connection by gas phase

- Continuous gas phase connection CIVa-CV at different conditions in CV (set points of % O_2)

- CIVa illumination adjusted by the control system to produce the oxygen necessary to maintain set-point of O_2 in CV, according to the knowledge model linking O_2 production and illumination

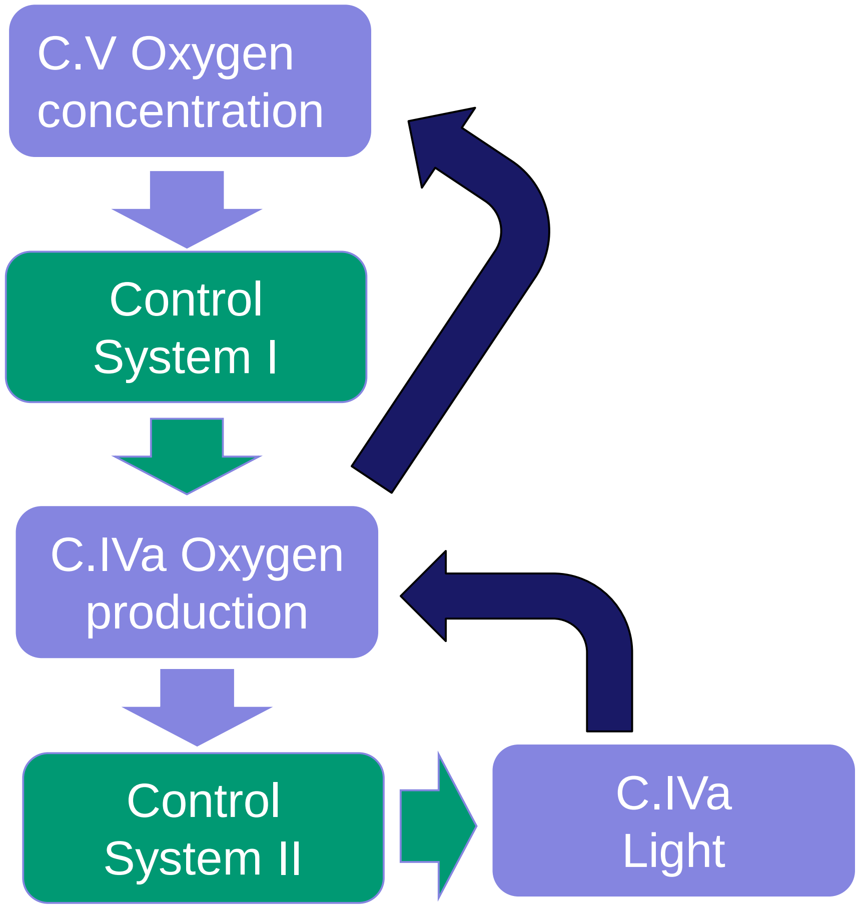




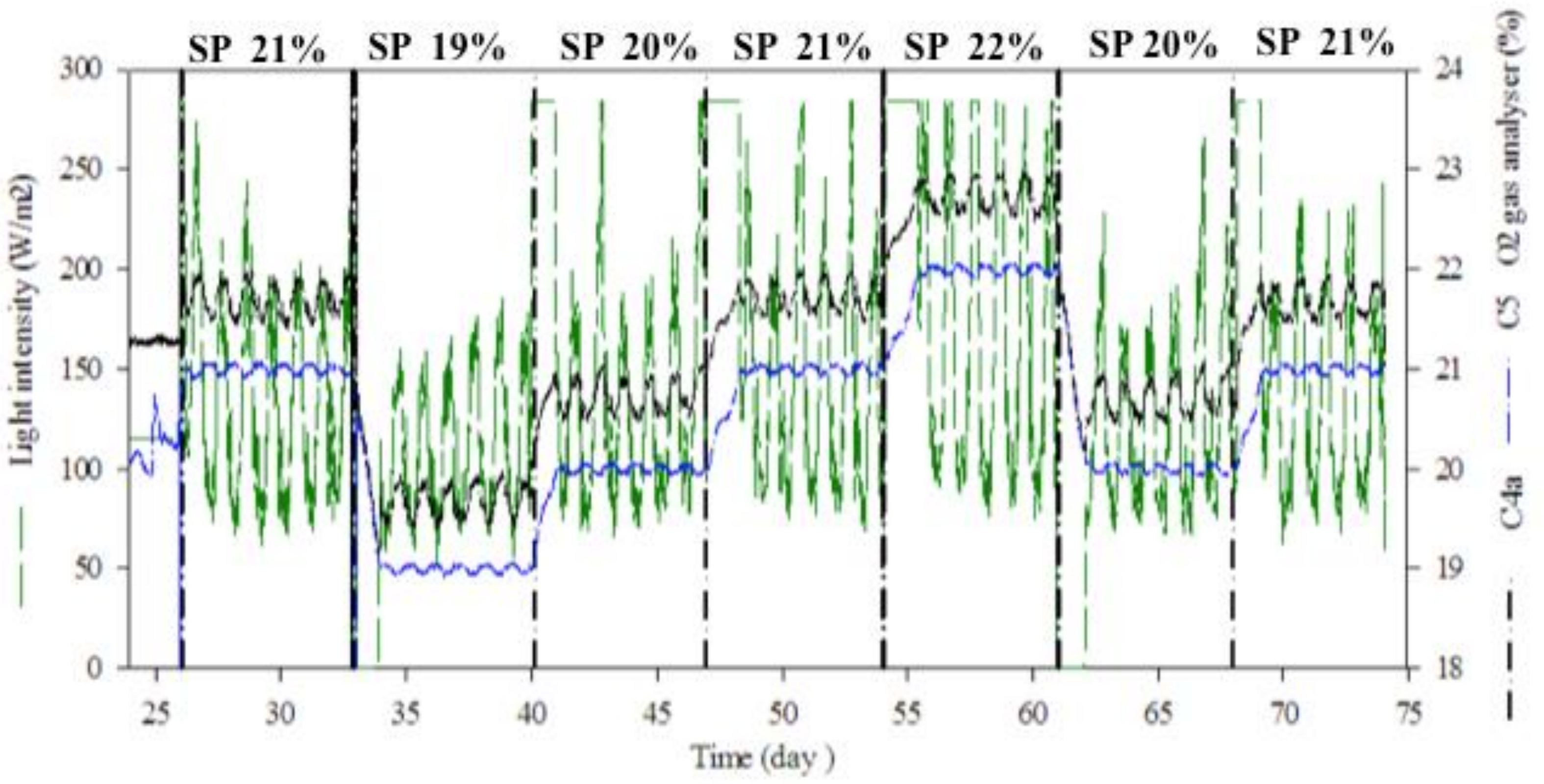
WP1 integration. Experimental results.

CIVa + CV sequential test

Oxygen – Light control system

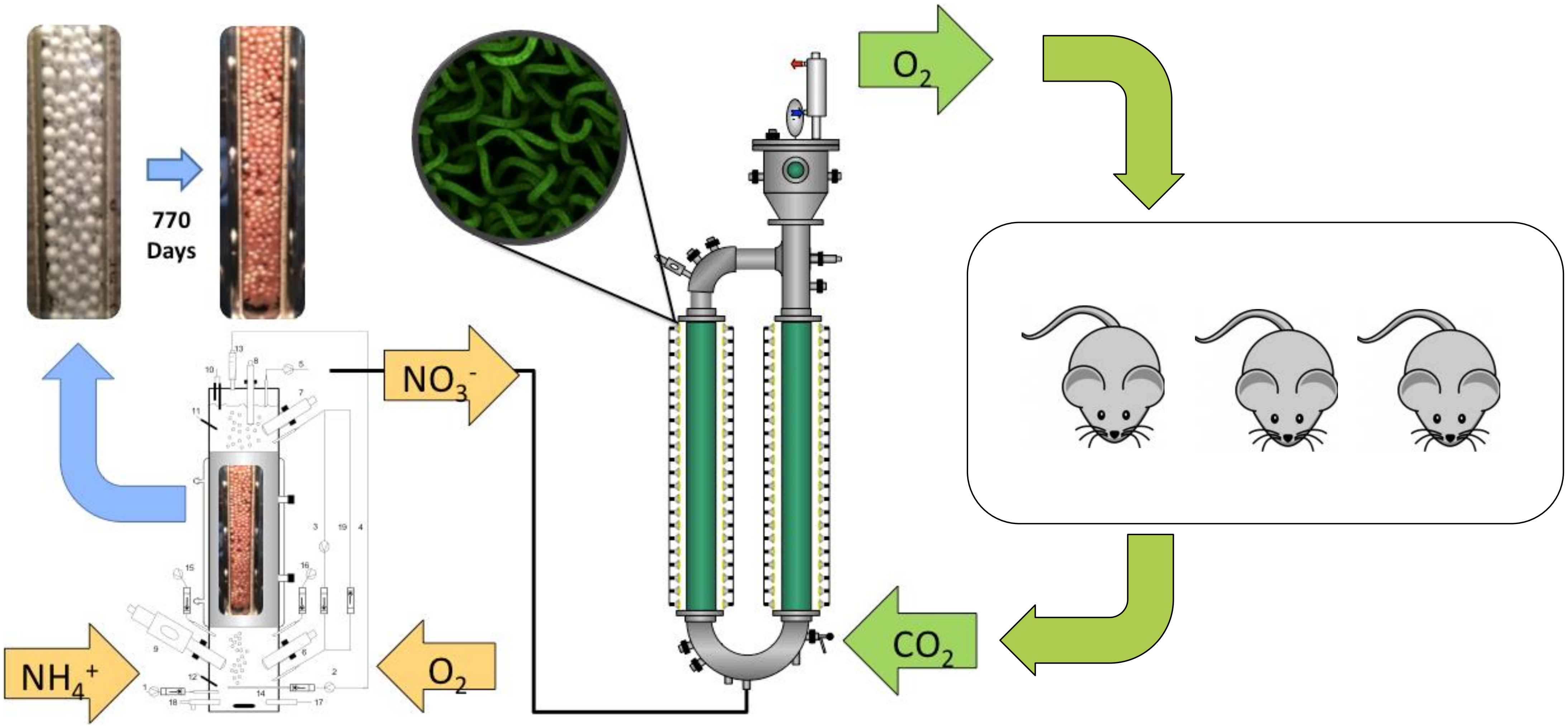


Light and Oxygen evolution in CIVa and CV compartments

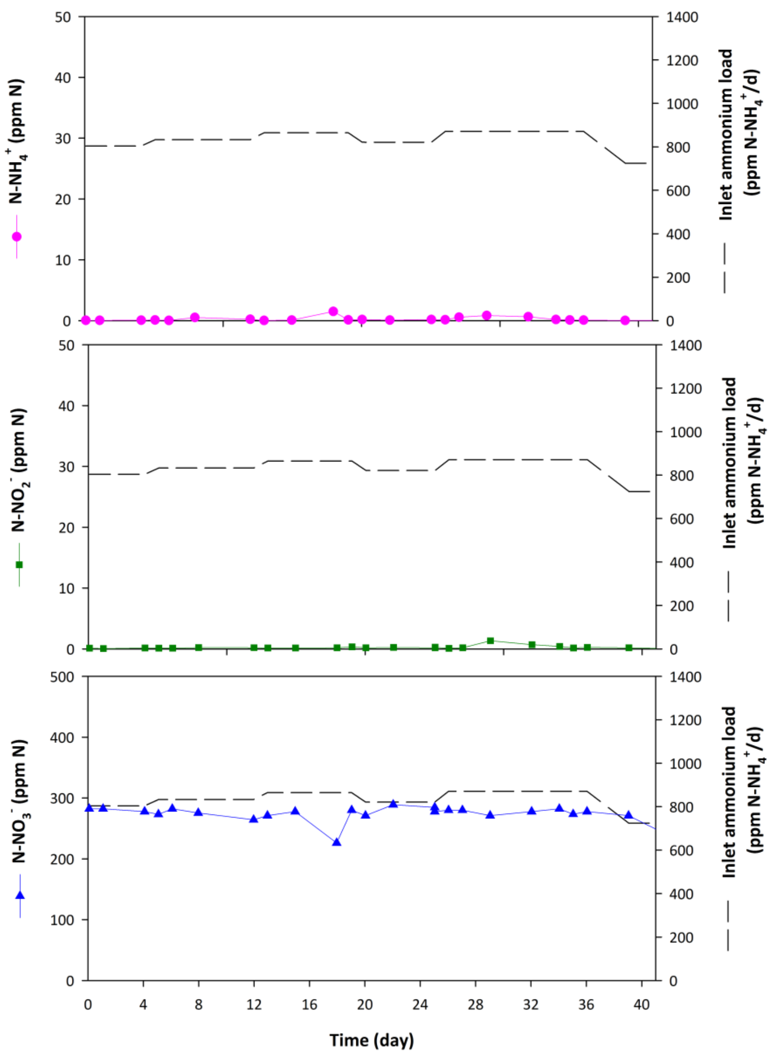


The system response to CV oxygen set point changes is consistent in the range tested.

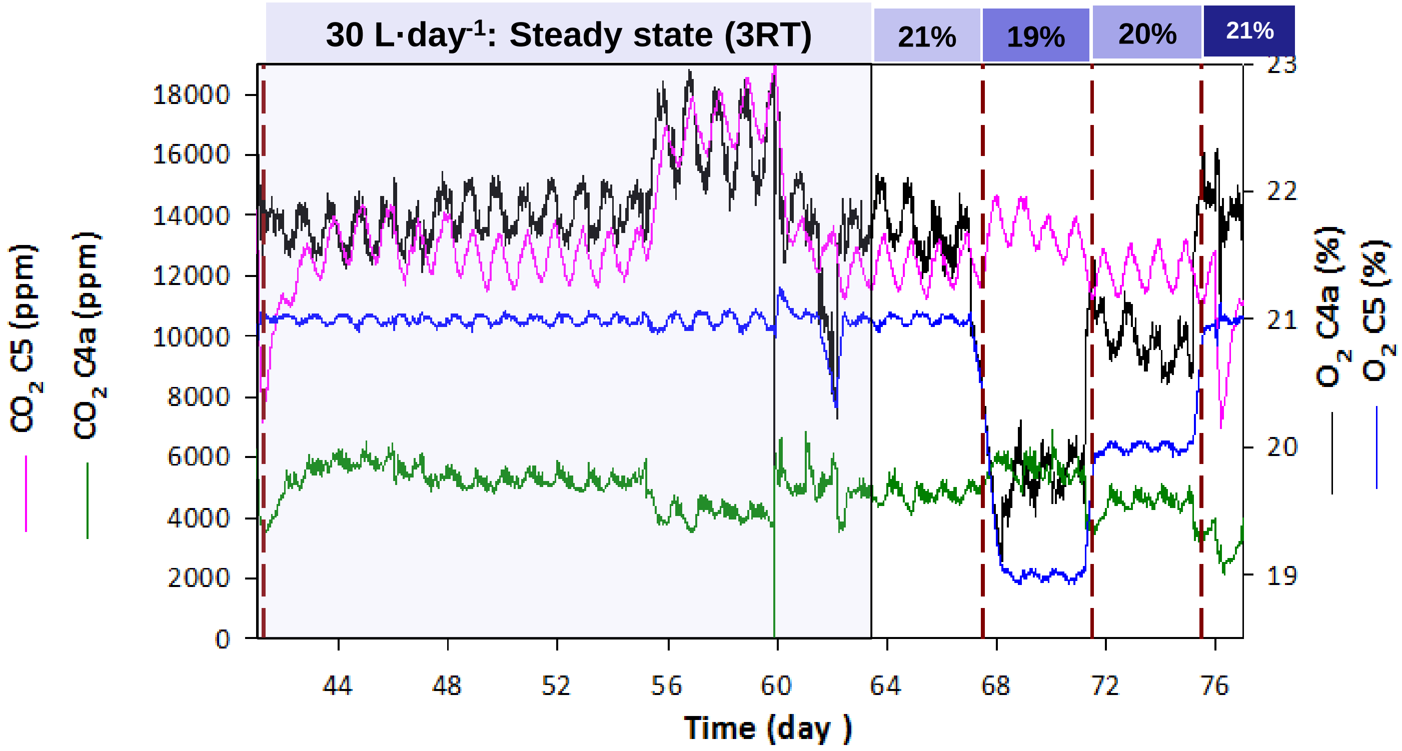
WP4 integration. CIII + CIVa connection by liquid phase and CIVa + CV by gas phase



WP4 integration. CIII + CIVa connection by liquid phase and CIVa + CV by gas phase



- All compartments operating in continuous mode and connected for several months
- Dynamic and static operation under control system fully demonstrated



MELiSSA Pilot Plant: a team effort

Acknowledgements

MELiSSA Partners

ESA (EU), SCK/CEN (B),
University of Ghent (B),
VITO (B), Enginsoft (I)
SHERPA Engineering (F) ,
University Clermont Auvergne (F),
University of Guelph (CND),
Université Mons Hainaut (B)
IP Star (NL), Univ. Napoli (I)
Univ. Lausanne (CH)

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Jolien de Paeppe
Carles Ciurans

Funding

ESA (several programs), several national delegations (Spain, Belgium, Canada, Italy, France, Norway)
UAB
SEIDI, CDTI, GdC

MELiSSA ESA-ESTEC

Christophe Lasseur
Brigitte Lamaze
Christel Paillé
Pierre Rebeyre

MELiSSA: from the concept to a solid reality through a collaborative effort

The MELiSSA Pilot Plant was dedicated
on April 26th, 2011 to

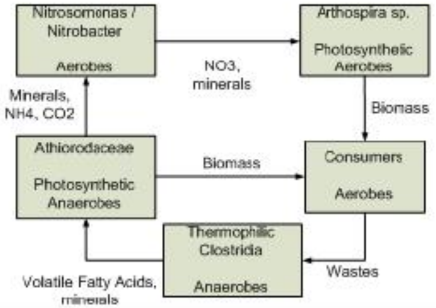
Claude Chipaux (1935-2010),

Founder of the MELiSSA Project,
As a tribute to his visionary and pioneering contribution
in the field of Closed Life Support Systems

*"Sur la lune, il y a des enfants
Qui regardent la terre en rêvant.
- Croyez-vous qu'aussi loin
Il y ait des humains?"*

*"On the Moon are children
Who see the Earth and wonder.
- Could there be some human-kind
Far away, out yonder?"*

The first MELiSSA loop concept



Mergeay, Verstraete, Dubertret, Lefort-Tran, Chipaux, Binot (1988)
"MELiSSA – A micro-organisms based model for CELLS development".
Proc. 3rd Eur. Symp. Spac. Therm. Con & LSS, Noordwijk NL, 3-6 Oct 1988

The lake, a model ecosystem

The future MELiSSA loop...