MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

IN COOPERATION WITH
esa
European Space Agency

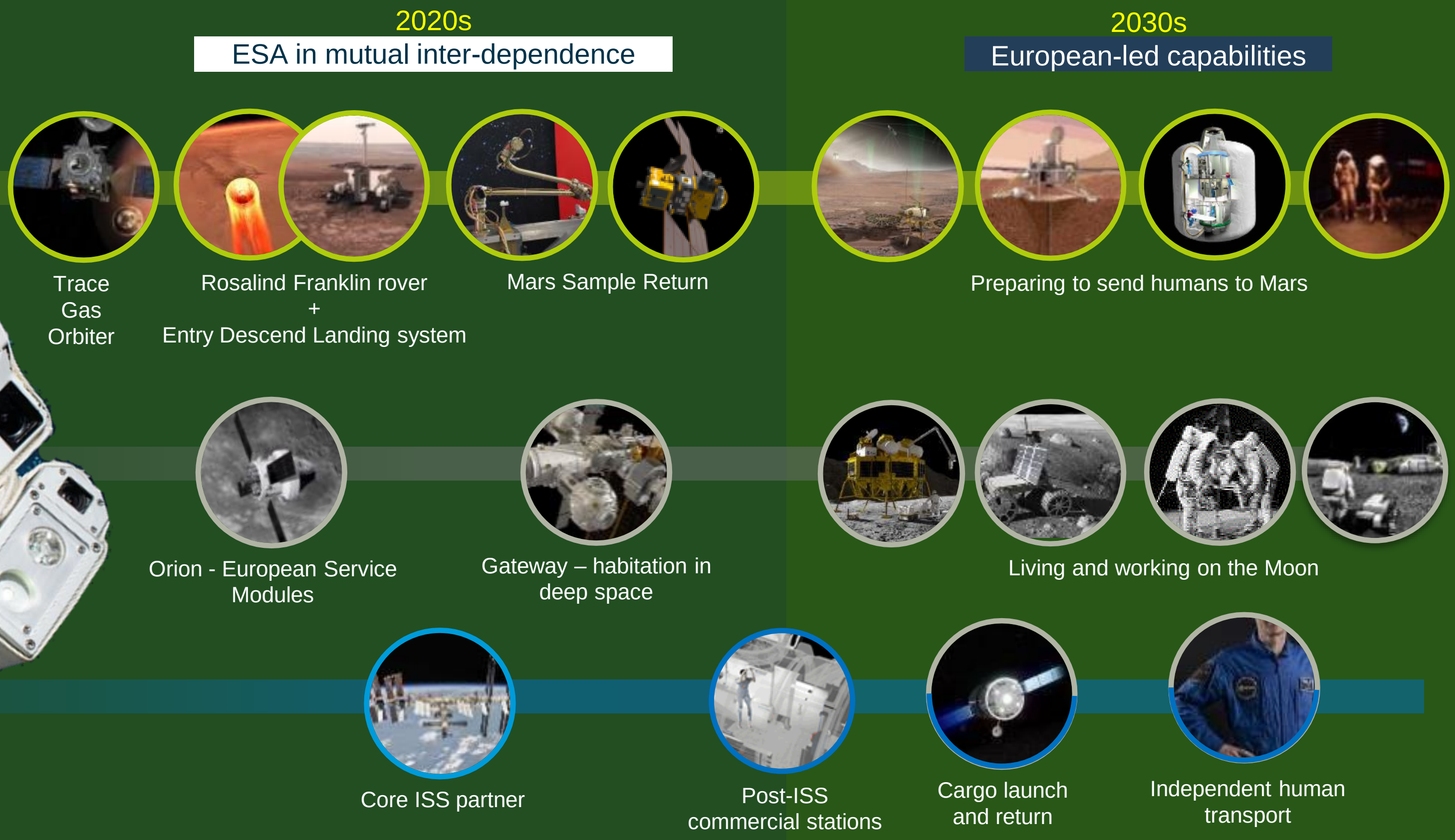
CREATING A CIRCULAR FUTURE

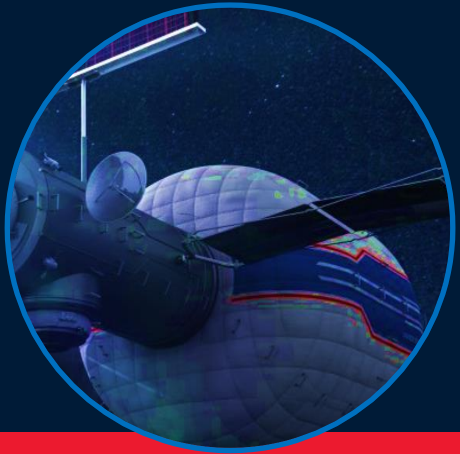
Introduction to MELiSSA

Ch.Lasseur, C.Paillé, C. Audas, S.Ortega, B.Lamaze, , S. Speidel, A. De Clercq

November 8th, 2022,

SEEKING MORE PROMINENT ROLES





Description

- Future human round trip Mars missions requires a highly optimised and reliable habitat as a core element.
- A ground based analogue Mars Transit Habitat(MTH) would provide an important test bed to develop, integrate and validate the required systems and technology with humans in the loop
- Prepares ESA for contributing critical elements to future human Mars exploration missions

Mars Transit Habitat Ground Based Demonstration Facility

Technology

- **Advanced Life Support technologies**
- **Resource management, waste treatment and recycling**
- Crew health medical support & countermeasures
- Habitat systems integration
- Autonomous operation & support to decision making(AI, virtual presence…)
- Food production, processing and preparation

Science

- Science possibilities include
  - human-subject and human-tended
  - Support of human habitation (e.g. food and nutrition, pyschological)
  - Validation of countermeasures
  - Physical sciences studies (e.g. multiphase processes)

Schedule

- CDF H2 2022
- Potential Phase A/B1 2023-2025
- Potential Phase B2-C-D Implementation decision at CM25 for development and operation of Mars Transit Habitat ground based demonstration facility in E3P4
- Note: favouring challenge-based innovation non-space industry, SMEs,…

MELiSSA

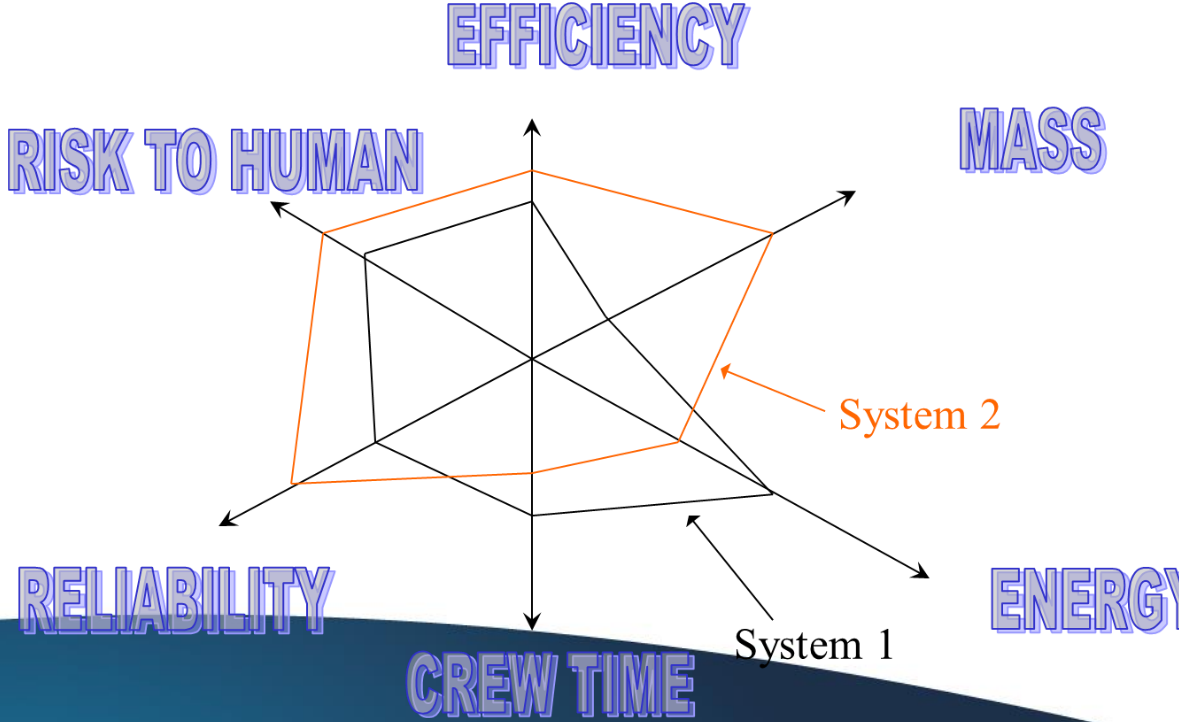
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

The Challenge

How to assemble processes and technologies to reach the highest level of closure and the highest Safety ?

ALiSSE Criteria

- Multi-parameters metric to evaluate and compare ECLSS:
  - Efficiency
  - Mass
  - Energy & power
  - Crew time
  - Risk for human
  - Reliability
  - Sustainability



High Process Diversity

- Anaerobic thermophile,
- MEC
- New fabric,
- Fixed-bed reactors
- Bio-packaging,
- Membrane bioreactors,
- Gas/liquid separation/mixing,
- Solid liquid separation,
- Catalysers,
- Photo-bioreactors,
- Nitrification/Denitrification
- Membrane technologies
- Microbial Food,
- Higher plants
- Microgreens,
- Artificial meat,
- 3D printing,

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Somes Challenges

- Circularity,
- 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,
- …..

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The Project

- Seeded in 1987, by AIRBUS- France,
- ~50 organisations,
- 14 Countries.

Memorandum of Understanding

- Binding document,
- Signed by 15 partners,
- Coordinate by ESA,
- Two boards per year,
- Applicable document to all contracts,
- Evolution to ease collaboration & commercial applications

A Team

Industry

ESTEE
EARTH SPACE TECHNICAL ECOSYSTEM ENTERPRISES

ThalesAlenia Space
a Thales / Leonardo company

SHERPA ENGINEERING

beyond gravity

ENGINSOFT

QINETIQ

BioX technologies

BLUE HORIZON

SPARTAN SPACE

frontiers

ESA-Team

Activities 2019-2022

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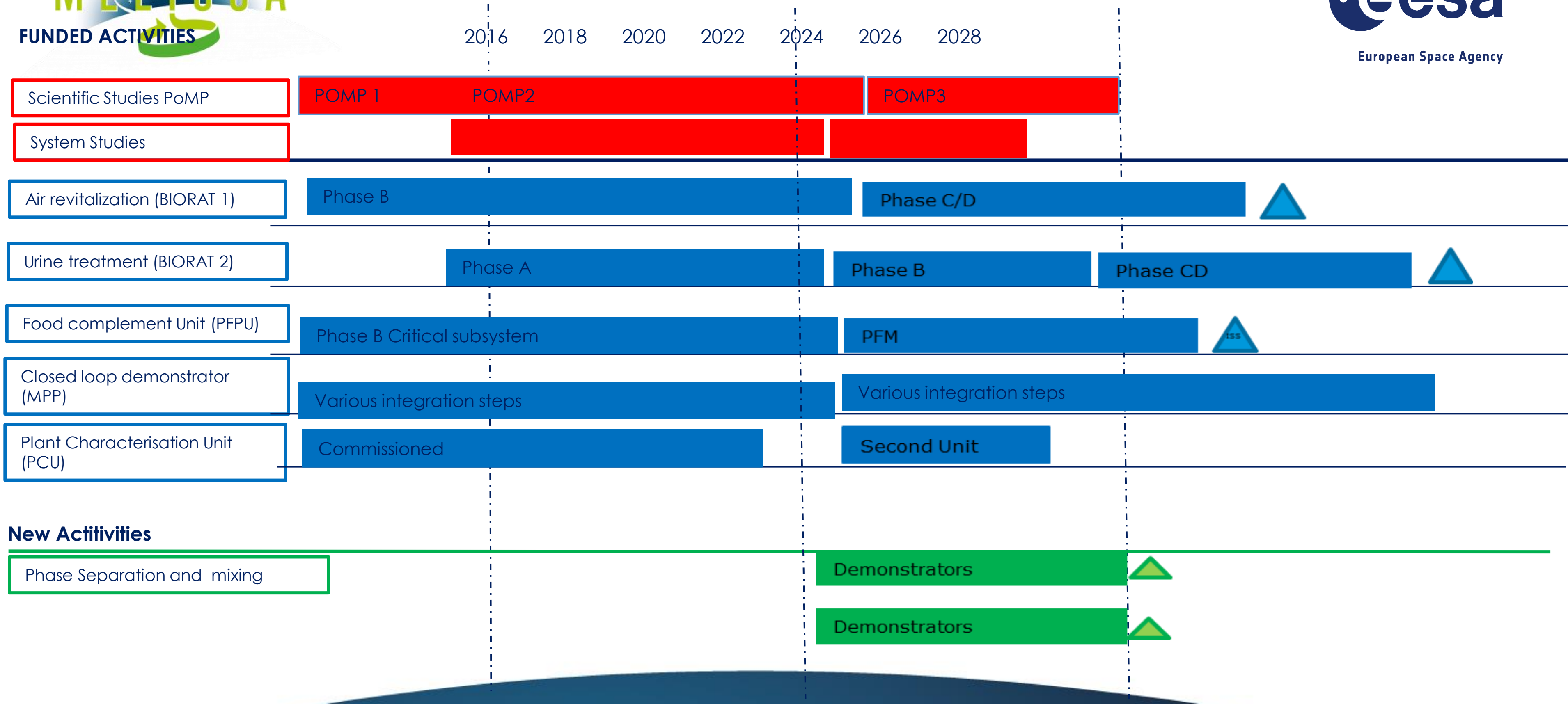

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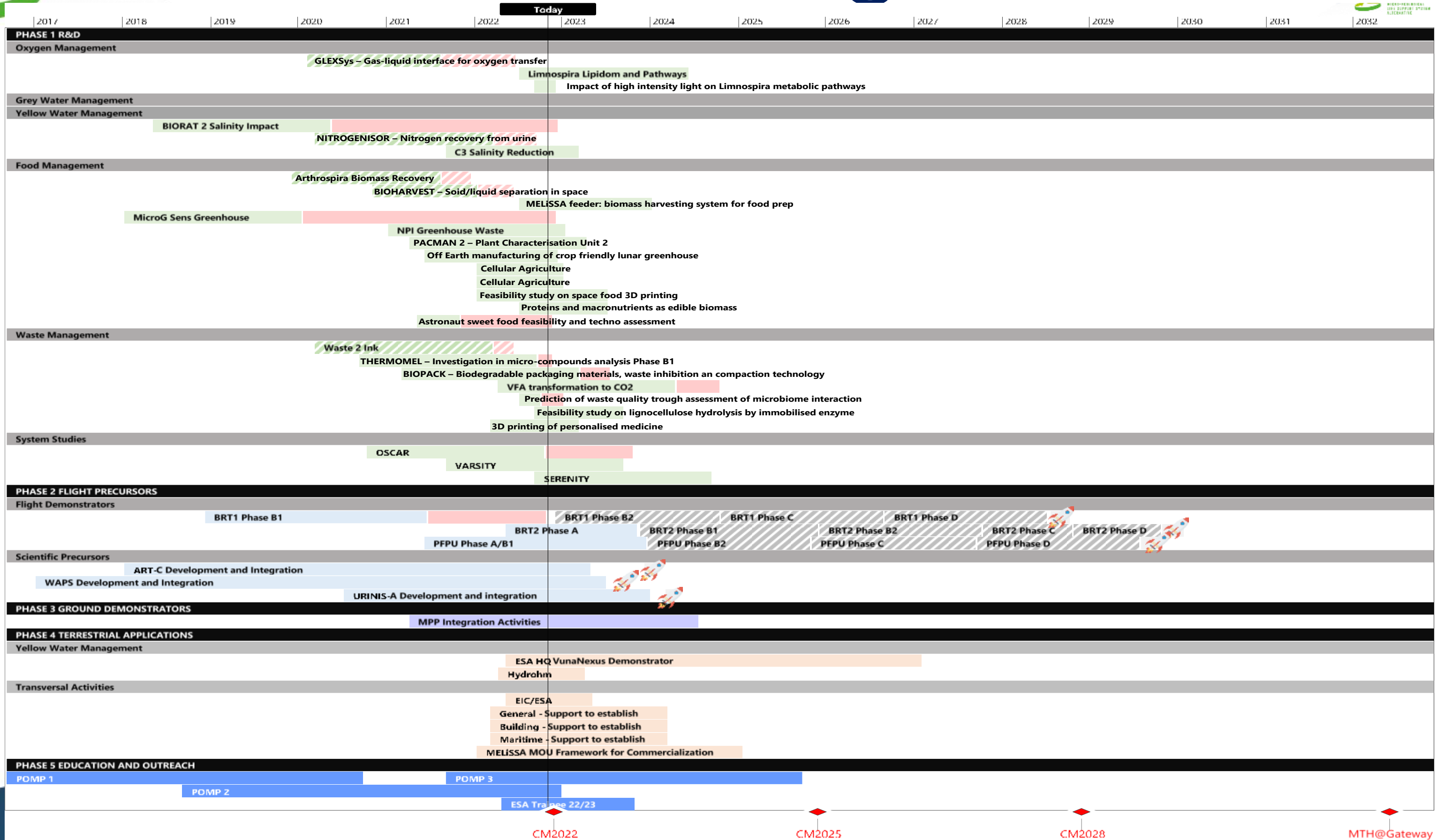
Planning



INTENSIVE CHARACTERISATION

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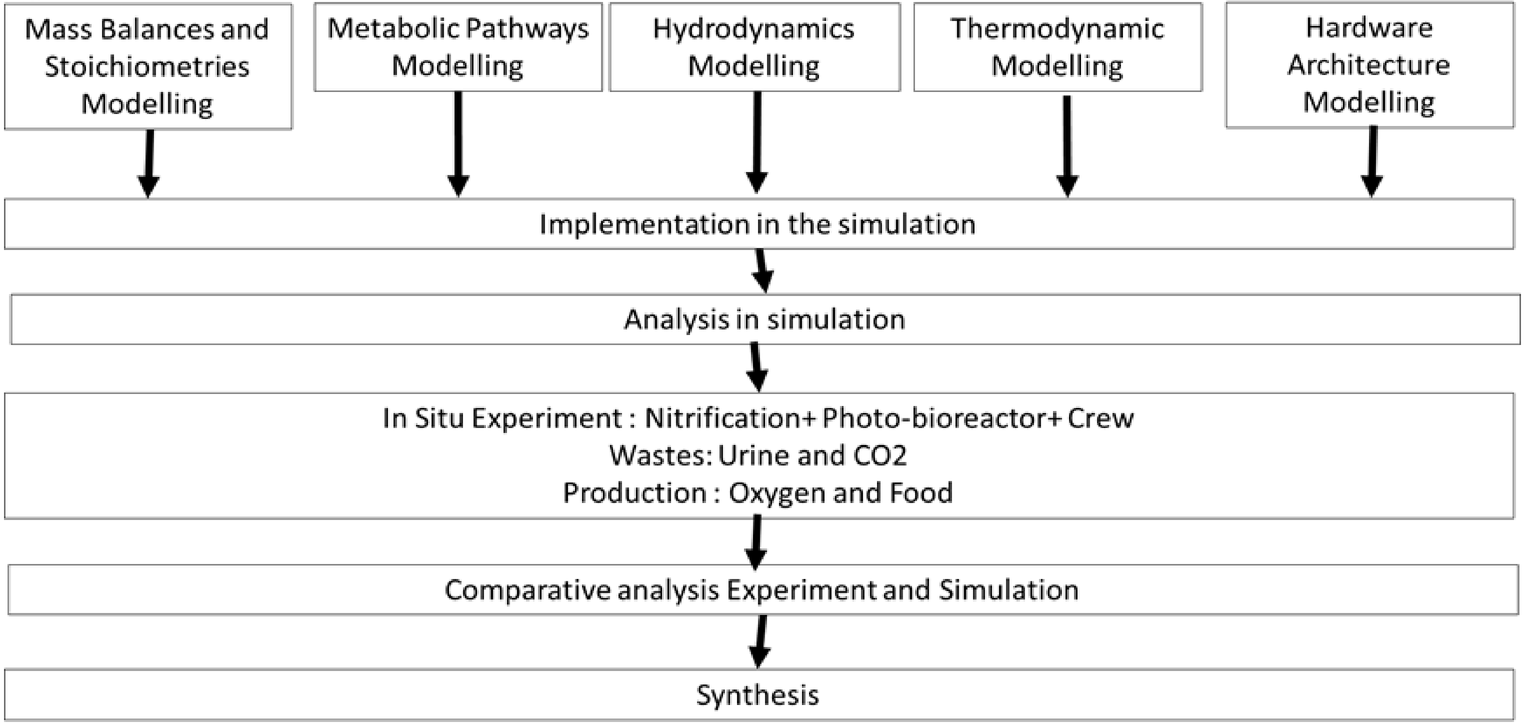
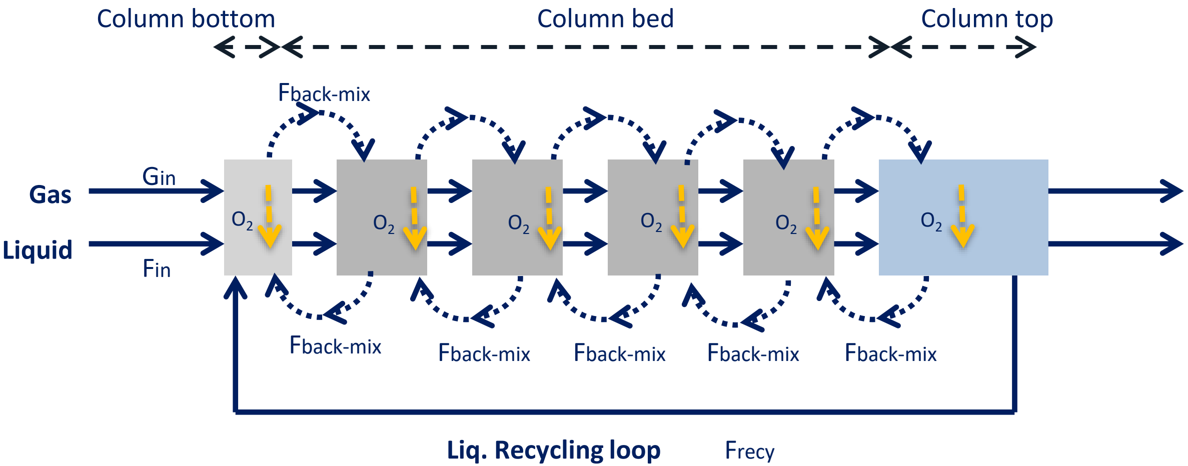
Multi-Layer Approach



N-tanks in series



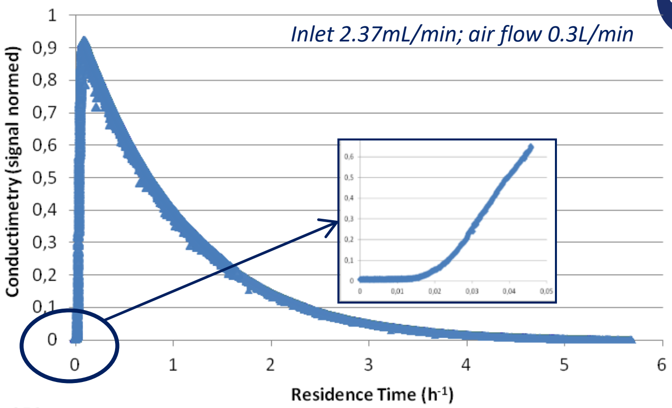
Mass balance equation:

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

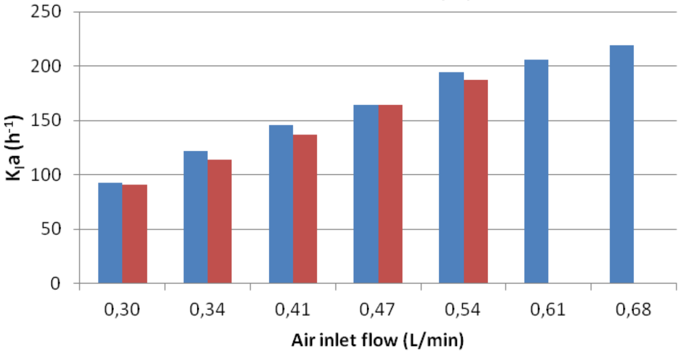
$$+ VL^n.RLs^n + VL^n.RFs^n \quad \text{Bioreaction (Pirt model)}$$

$$+ VL^n.EGLs^n \quad \text{Gaz/liquid exchange ratio}$$

- DTS:
  - → Tr=4.19h^{-1}
  - → Liquid perfectly mixed



- k_La:
  - → Reproductible results
  - → 92.2h^{-1} for 0.3l



Liquid perfectly mixed but fixed biomass : n-tank model conserved

Control strategy

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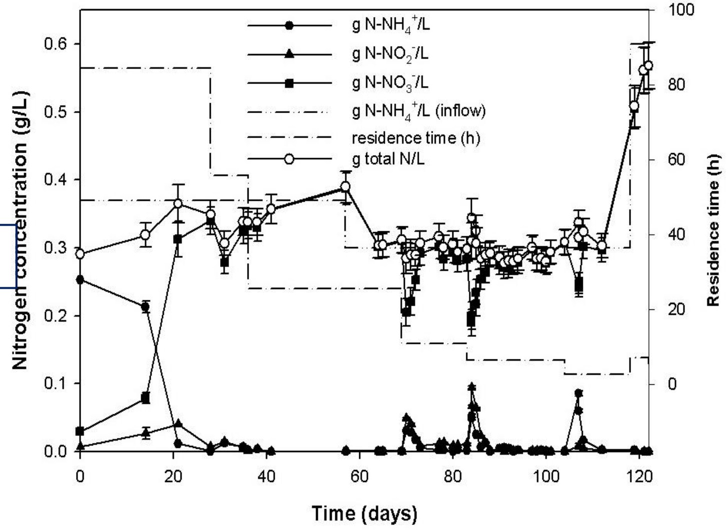
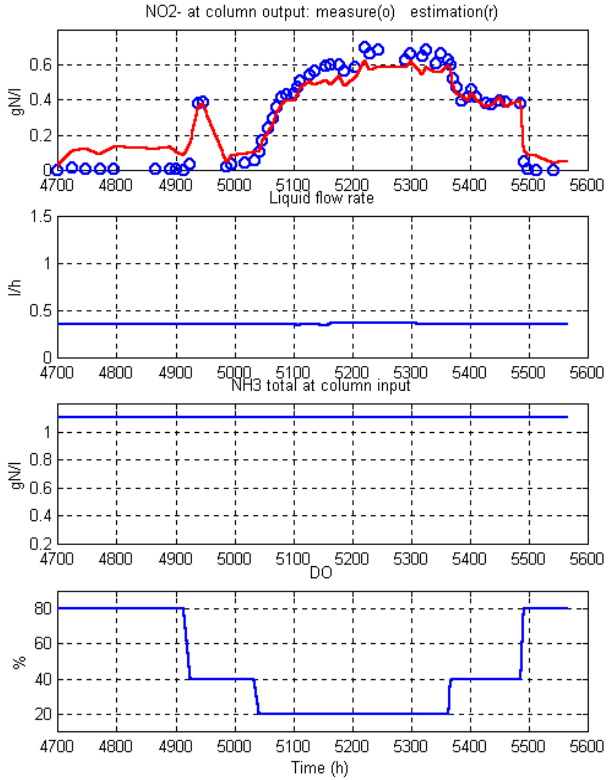
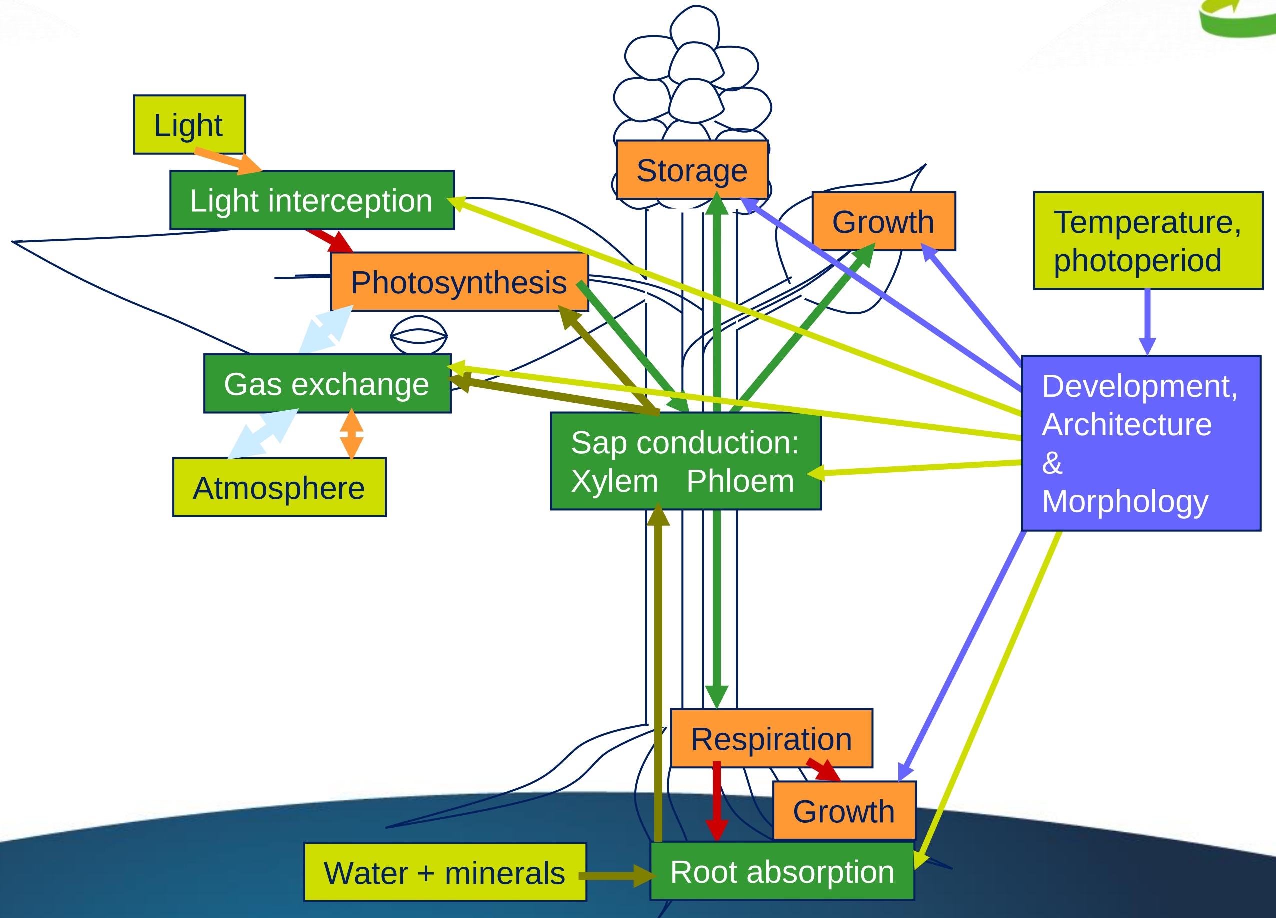




Variation of the Dissolved Oxygen

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

PCU delivery, November 4/5th, 2019, Napoli

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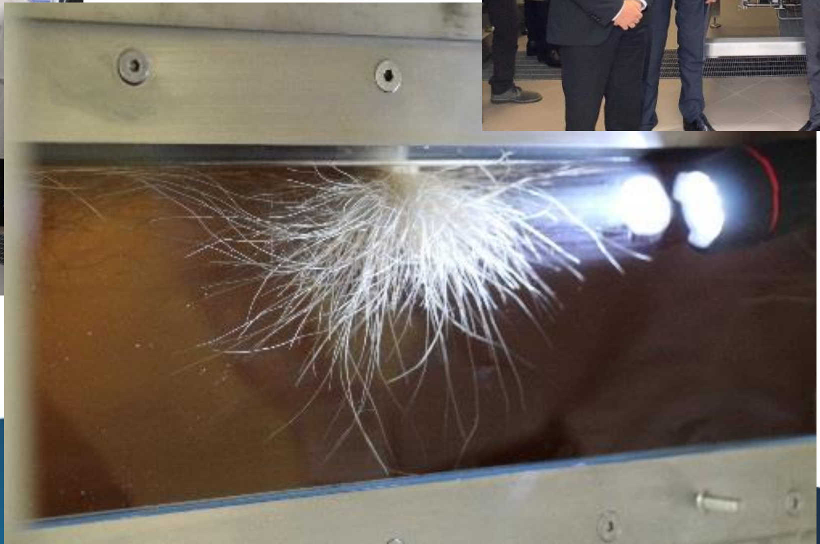
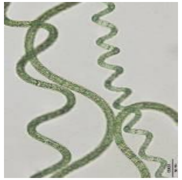
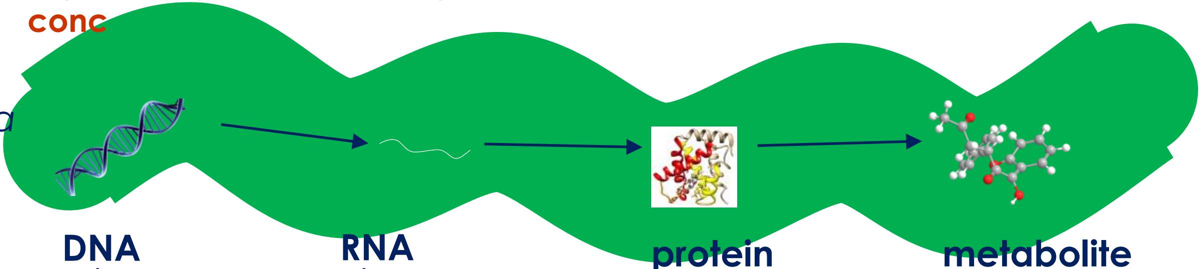


Molecular analysis of the micro-organisms

High-throughput Technologies, on small sample volumes, low biomass conc

Arthrospira



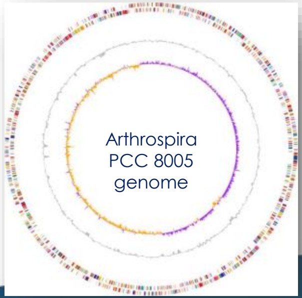


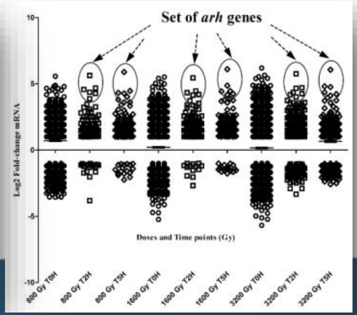
DNA → gene stability → genomics

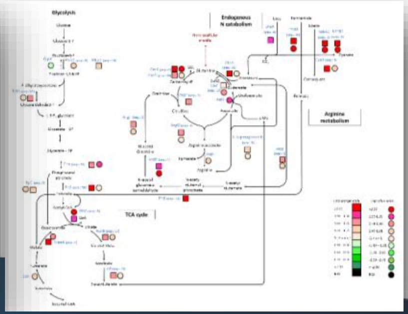
RNA → gene expression → transcriptomics

protein → protein expression → proteomics

metabolite → metabolite production → metabolomics







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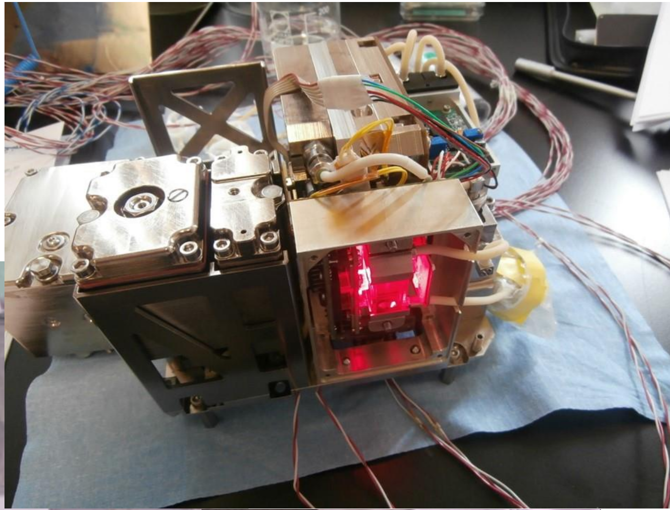
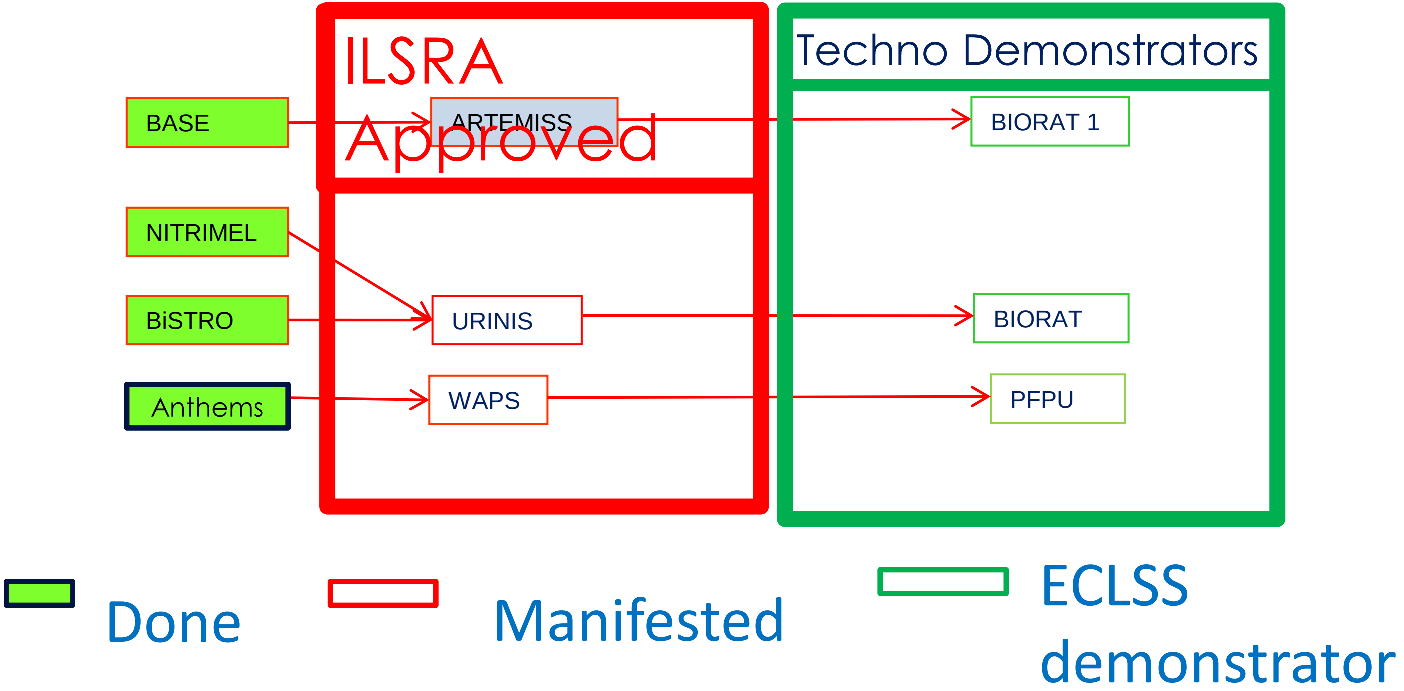
SPACE DEMONSTRATORS

Flight Experiments

MESSAGE 1 (ISS) 2002
MESSAGE 2 (ISS) 2003
MOBILIZATION (ISS) 2004
BASE A (ISS) 2006
BASE B&C (ISS) 2008
NITRIMEL (Foton) 2014
MELONDEAU/BISTRO (ISS), 2015
ArtEMISS B (ISS) 2017-2018
ArTEMISS-C ISS Manifested, 2023 (TBC)
URINIS-A ISS (2024 TBC)
WAPS ISS (2023-2024 TBC)
Call for applications (in progress)



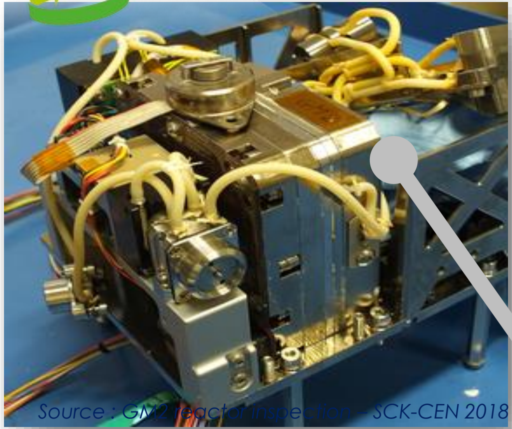
Space Demonstration Logic



ARTEMISS Experiment

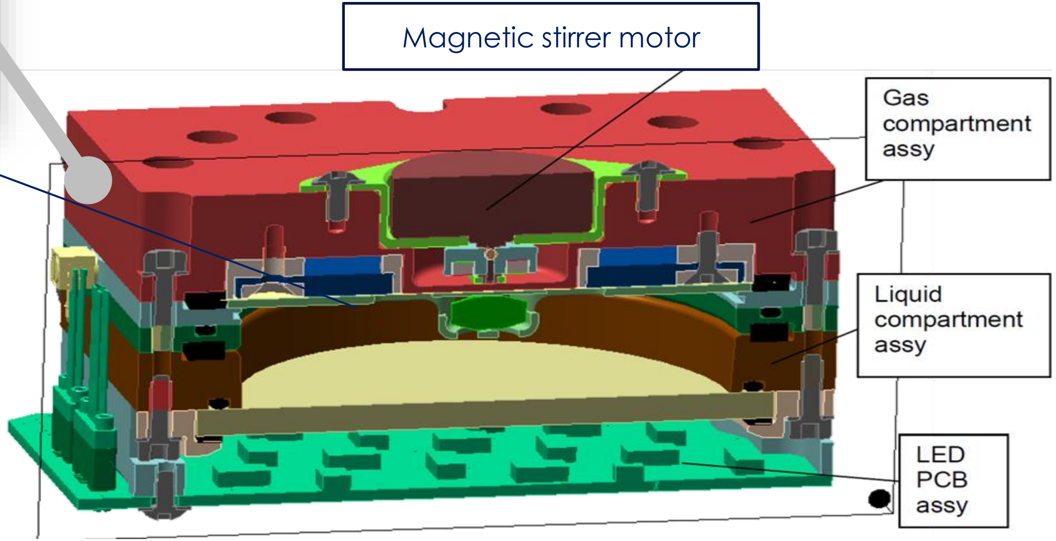
- on-line assessing of growth of *A. platensis* on ISS by gas pressure measurement

- Photobioreactor → analysis using a classical approach for bioprocesses : modelling and simulation



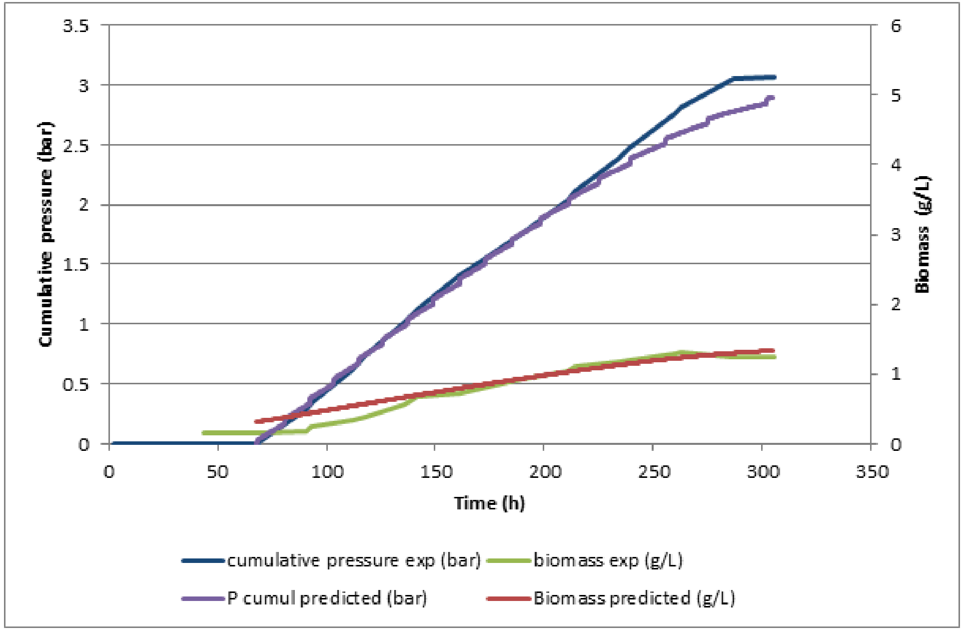
Source : GM2 reactor inspection – SCK-CEN 2018

PTFE membrane (G/L)



ARTEMISS Results

- 1) Axenic Culture,
- 2) Gas/Liquid Separation,
- 3) Oxygen production and quantification,
- 4) Validation of Predictive model

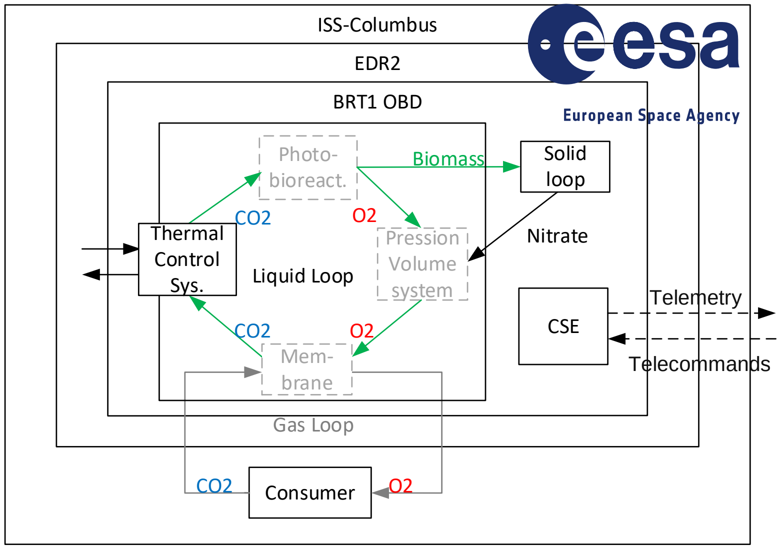


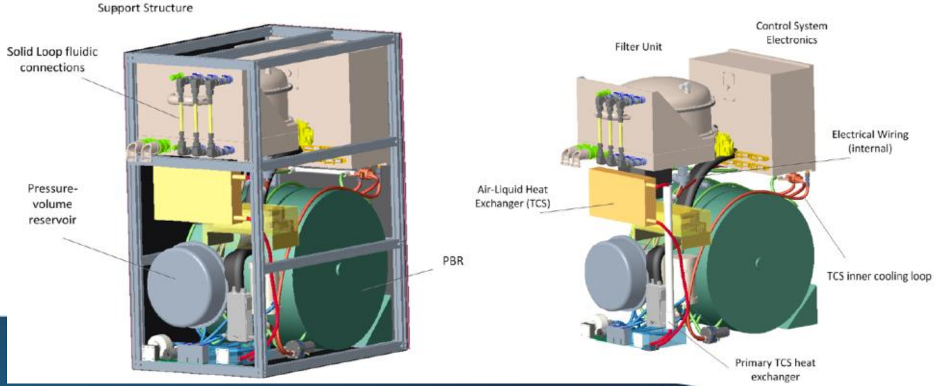
PHOTOBIOREACTORS

- Accommodation Requirements
  - Telemetry / telecommands (bi-directional communication)
  - Thermal interface (800W dissipation capacity)

- BIORAT 1 On-Board Demonstrator is composed of 5 sub-systems interconnected and inter-dependant
  1. Liquid Loop (incl. Photo-bioreactor)
  2. Gas Loop
  3. Solid Loop
  4. Control System Electronics
  5. Thermal Control System

- The 5 sub-systems are composed of the following internal elements (see right drawing)





PhotoBioreactors

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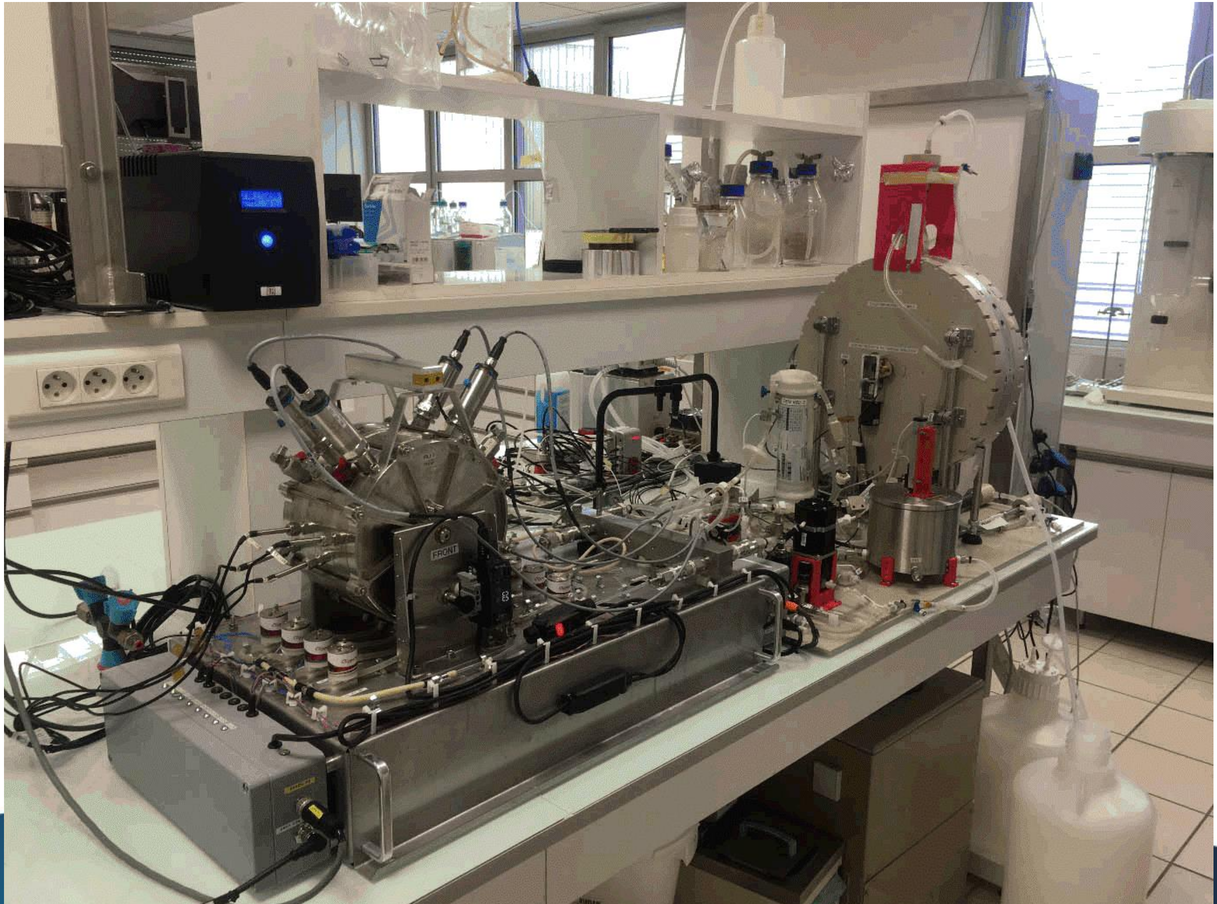

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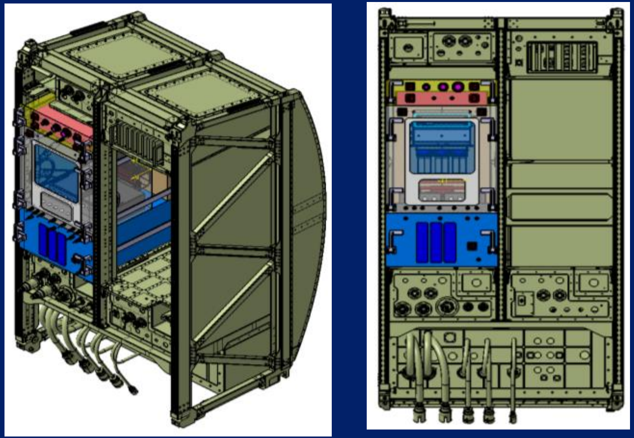
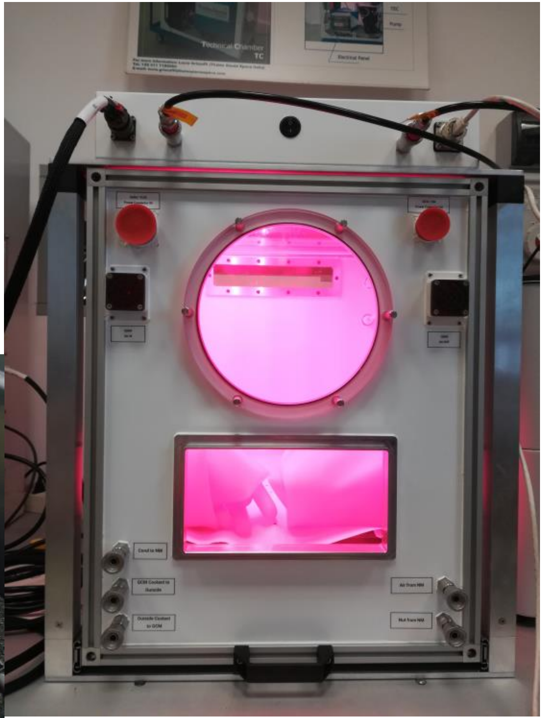
- **Demonstrator** for production of tubers (potatoes) on the **ISS**
- Realized as an Experimental Insert for **EDR MK II**
- Consisting into **3 drawers**

PFPU within EDR2





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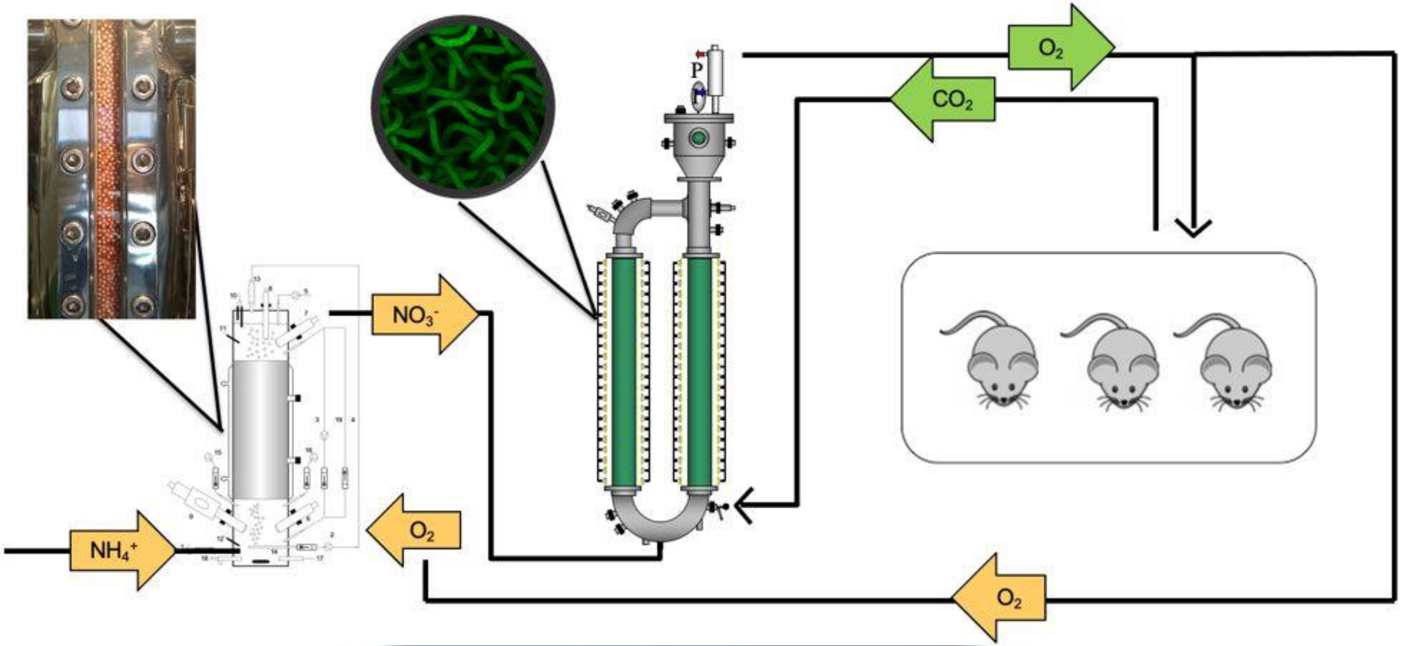
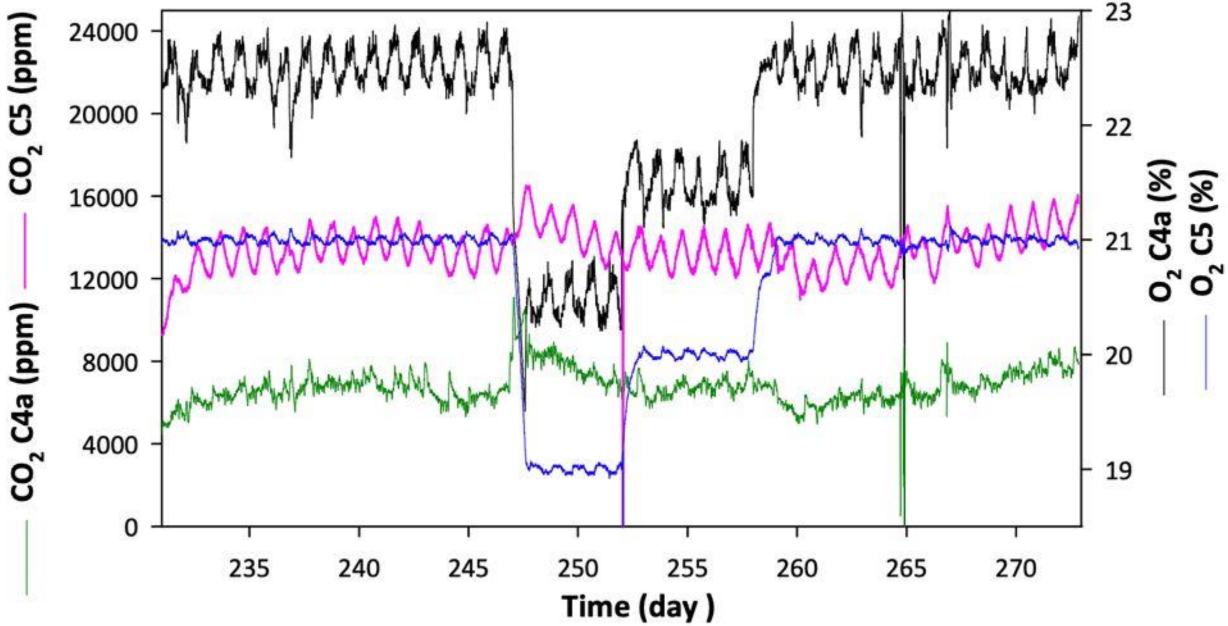
GROUND DEMONSTRATORS

The Pilot Plant

CO2+ Urine

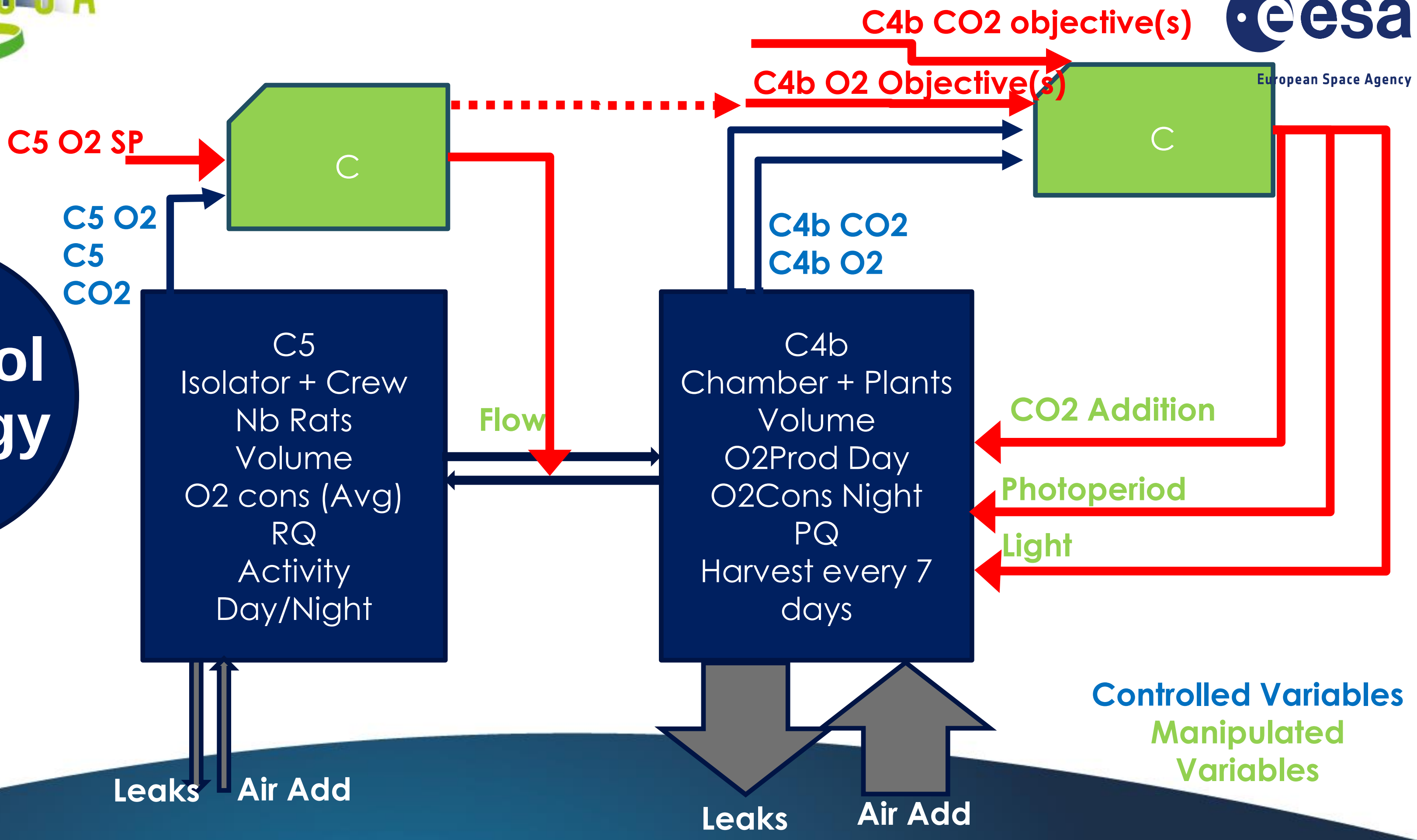


= O2+ Proteins



CO_2 C5 (ppm)
CO_2 C4a (ppm)
24000
20000
16000
12000
8000
4000
0
235
240
245
250
255
260
265
270
Time (day)
23
22
21
20
19
O_2 C4a (%)
O_2 C5 (%)

Control Strategy



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COMMERCIAL APPLICATIONS

HYDROHM- Ghent Recreatie Park

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2020/2021 : Grey Water Recycling
2023: Grey Water + Yellow Water Recycling

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BELEM Agreement

Agreement MELiSSA/BELEM:

- Pilot demonstrators for grey, yellow and black water,
- Objectives: No release of human wastes when on Sea, via recycling on board.

CimentAlgue

- CO_2 removal,
- 2 Meu investment
- Design of MELiSSA photo-bioreactors
- VICAT + ADEME

French Guyana

- Largest micro-algae production plant in Europe
- Design based on MELiSSA Photo-Bioreactors Know-how
- Targeting several markets: biofuels, food,
- Investment of 4 Meu

File Edit View History Bookmarks Tools Help

Innovation & Ecologie industri ×

https://u-news.univ-nantes.fr/innovation-ecologie-industrielle-culture-a-grande-echelle-de-microalgues-en-guyane

Getting Started ONE ESA

Nantes Université

News

Ne rien manquer de notre actualité

U-NEWS > VERSION FRANÇAISE > UN BUSINESS NEWS

Développement durable | Partenariats | Relations Entreprises

Innovation & Ecologie industrielle : culture à grande échelle de microalgues en Guyane

Le 09 février 2021

Communiqué de presse

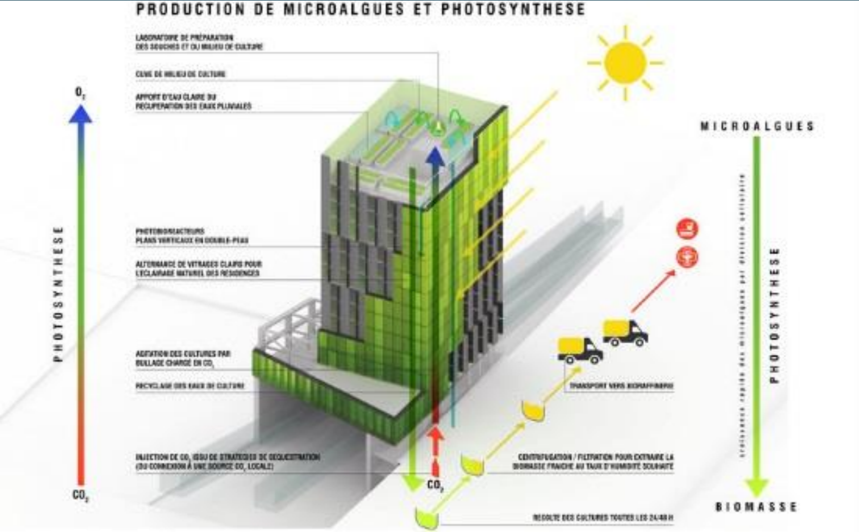
Lauréat d'un appel à projet du Programme d'Investissement d'Avenir (PIA3), géré par l'ADEME, le projet PIAN, porté par la SARA (Société Anonyme de Raffinage des Antilles) avec le laboratoire du GEPEA de l'Université de Nantes démarrera en février 2021. Cet ambitieux projet d'écologie industrielle concrétise la réalisation en Guyane d'un démonstrateur XXL, le plus grand jamais construit en France sur le sujet. L'objectif ? Créer de nouvelles filières durables basées sur la valorisation biologique du CO2 industriel, à travers la production à grande échelle de microalgues.

Innovant à bien des égards, il s'appuie sur plusieurs projets de recherche, pour déployer les microalgues en biocarburants troisième génération, en biomatériaux et

AlgoSource

POUR EN SAVOIR PLUS

- Le GEPEA
- ALGOSOLIS
- LA SARA
- ALGOSOURCE
- Capacités



Biofacades Paris XTU


Medical Mycology Advance Access published January 3, 2014

Medical Mycology, 2014, 00, 1–5
doi: 10.1093/mmy/myt017
Advance Access Publication Date: 0 2014
Short Communication

ISHAM INTERNATIONAL SOCIETY FOR HUMAN AND ANIMAL MYCOLOGY

Short Communication

Usefulness of pan-fungal NASBA test for surveillance of environmental fungal contamination in a protected hematology unit

Marie-Pierre Brenier-Pinchart[1,3,*], Hafid Abaibou[4], Thomas Berendsen[1], Gautier Szymanski[1], Messalia Beghri[4], Sébatien Bailly[1,3], Frédérick Lasnet[4], Anne Thiebaut-Bertrand[2], Claude Mabilat[4] and Hervé Pelloux[1,3]

[1]Laboratory of Parasitology and Mycology, [2]Department of Hematology, University Hospital, [3]Joseph Fourier University, Grenoble I, Grenoble, France and [4]bioMérieux S.A., Chemin de L'Orme, 69280 Marcy l'Etoile, France

Microbial Risk

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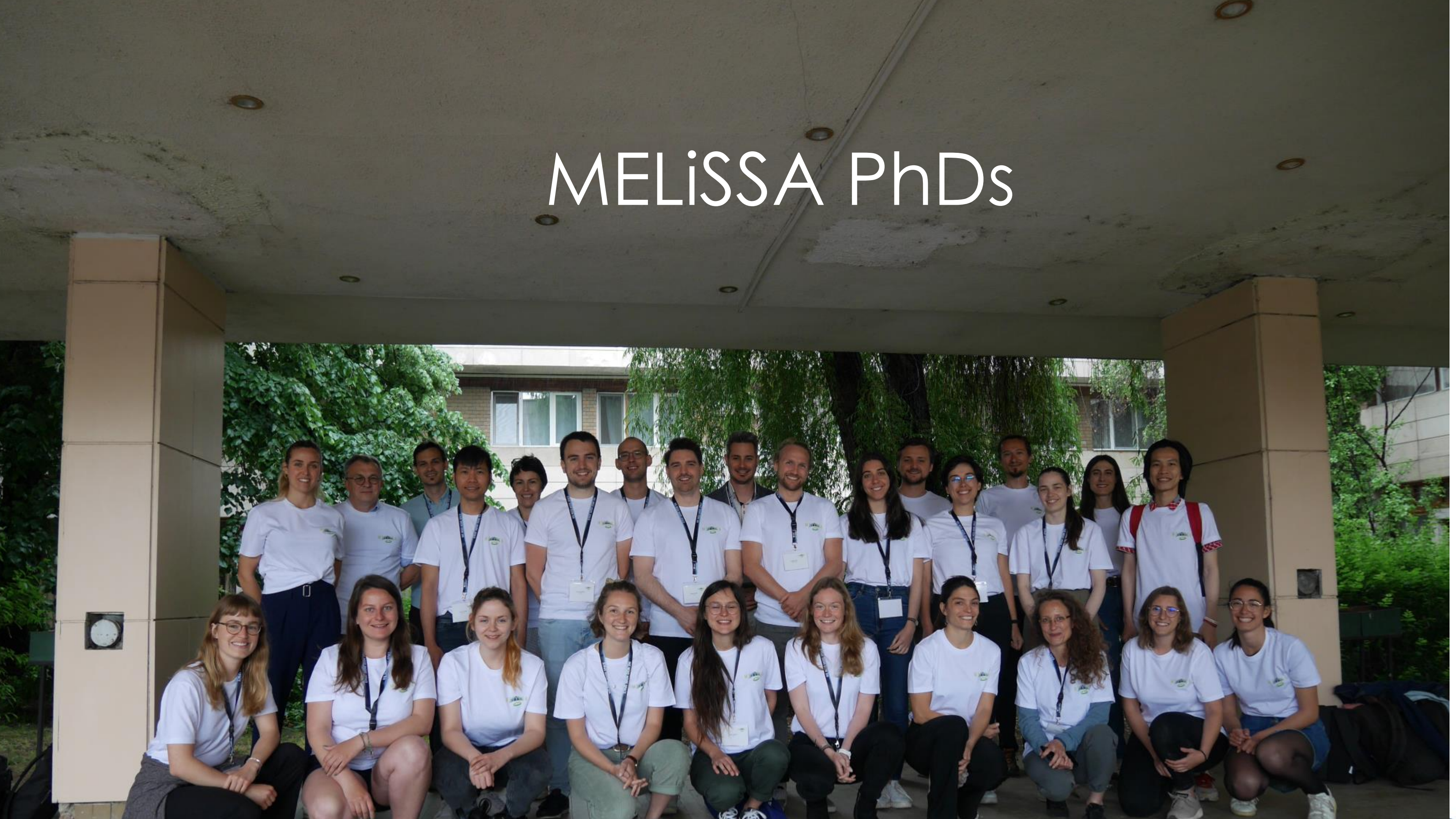
EDUCATION


MELiSSA PhDs

ESA_Lab@

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- CentraleSupelec,
- SupAero

IAC 2022: ESA DG visit with ISAE-Supaero

Primary Schools

frontiers | Frontiers in Astronomy and Space Sciences

frontiers

Presentations at the 2022 MELiSSA Conference – Current and Future Ways to Closed Life Support Systems

Topic Editors:

Cyprien Verseux
Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Germany

Jean-Pierre Paul de Vera
German Aerospace Center (DLR), Space Operations and Astronaut Training, Microgravity User Support Center (MUSC), Cologne, Germany

Luigi Gennaro Izzo
Department of Agricultural Sciences, University of Naples Federico II, Naples, Italy

Submissions open: http://fron.tiers.in/rt/42915

Abstract Submission Deadline 10 January 2023
Manuscript Submission Deadline 10 March 2023

Submissions open from:

Frontiers in Astronomy and Space Sciences

Frontiers in Microbiology

Frontiers in Plant Science

4.05
Impact Factor

List of Publications

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LasseurLiterature list about the MELiSSA Project and connected research (1988-2022) followed by seminal proceedings of 1987-1988

Legend of paper (or book chapters) topics/MELiSSA compartments:

LSS : Life Support Systems

SP: Space flight experiments and related studies (biocontamination, confined or extreme environments, space simulations (radiation, microgravity, low shear)

Mo: modelling

C1: MELiSSA first compartment (thermophilic, anaerobic, waste degradation)

C2: MELiSSA second compartment (anaerobic, photosynthetic)

C3: MELiSSA third compartment (nitrifying)

C4a : MELiSSA fourth compartment (microbial food production (spirulines (*Limnospira indica* ex:*Arthrospira*)))

C4b: MELiSSA fourth compartment (plant food production)

C5: Consumers compartment

MPP: MELiSSA Pilot Plant.

Year	Authors	Topic/MELiSSA Compartment	Title	Journal	Volume	Pages/DOI/ PMID..
2022	Ciurans C, Guerrero J M, Martínez-Mongue I., Dussap C-G, Marin de Mas I , Godia, F	C4b, Mo	Enhancing control systems of higher plant culture chambers via multilevel structural mechanistic modelling	Front. Plant Sci. 13:970410.		DOI.org/10.3389/fpls.2022.970410
2022	Kumar D, Tiwari A., Fontaine J-P	SP	Evaluation of water vapor condensation using the thermoelectric cooling technique by experimental and theoretical observations	Phys. Fluids	34, 102108	DOI.org/10.1063/5.0106434

1st Annual International
Space Ecology Workshop

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EVENTS

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280 participants

Summer University

- Every 2 to 3 years,
- Open to non-MELiSSA PhDs,
- Last one in May 2022, in Sofia Bulgaria,

Communication

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2018 DREAMS…

2018 Dream List

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- Clear, Harmonized and Robust European Strategy,
- High quality of the Scientific and Engineering approach ,
- Multidisciplinary exchanges, (e.g human physiology),
- Easier and Faster Access to Space,
- Easier and Stable financial source,
- International (outside of Europe) Collaboration,
- Economical : Terrestrial spin-in/Spin-out
- Societal:
  - Education,
  - Citizen participation, and support,
- We have more…..!!!

Modelling and Simulation

- From one organism/plant modelling to a functional community modelling,
- From CHNOSP elements to the complete Mendeleev table,
- From Mass balance to Thermodynamical models,
- Modelling of genetic/transcriptomic evolution,

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2022 DREAMS...

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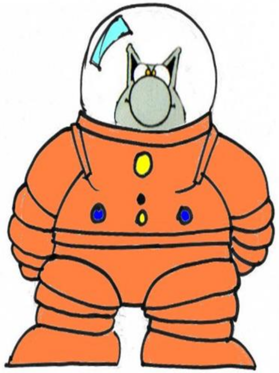
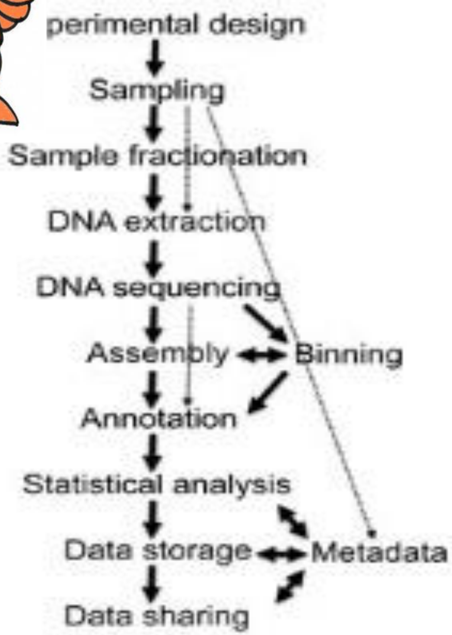
2022 Open Issues

- Functional Ecology,
- Genetic Stability,
- Food Engineering,
- Interface with Human physiology,
- Demonstration in LEO
- Synergies with Circular economy,
- Commercial success,





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THANK YOU.

Christophe Lasseur
Christophe.lasseur@esa.int

www.melissafoundation.org

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