MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

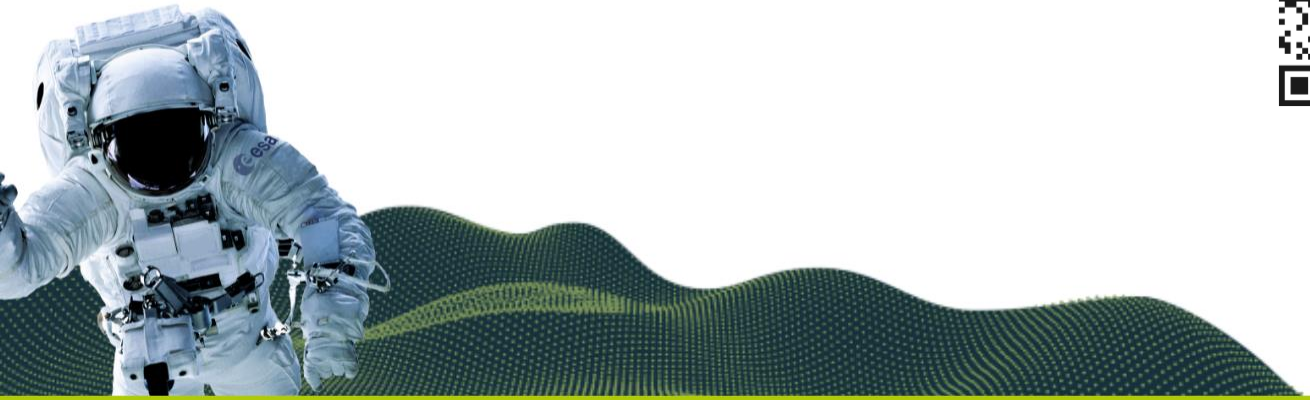
2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

PBRSpace R&D at MEG Science

Mattia Toffanetti

Our LinkTree



MEG Science
About us

MEG stand for Mutable Efficient Growing.

We are a consultancy firm that operates in the fields of applied photobiology for bio+agro-industry, serving as a link between laboratory research and feasibility-oriented industrial application.

15 years of experience with solid-state lighting (LED) and related technologies has led MEG to become a technology partner for leading-edge advancements.

Our aim is to be part of R&D&I oriented networks, to better expand and share our knowledge. Currently we are part of:

SPRING
Italian Circular Bioeconomy Cluster

AISAM

How we work
Our practice and specialties

We focus on technical lighting for non-human applications.

Our practice stems from a differentiated and horizontal background leveraging hard and soft skills from:

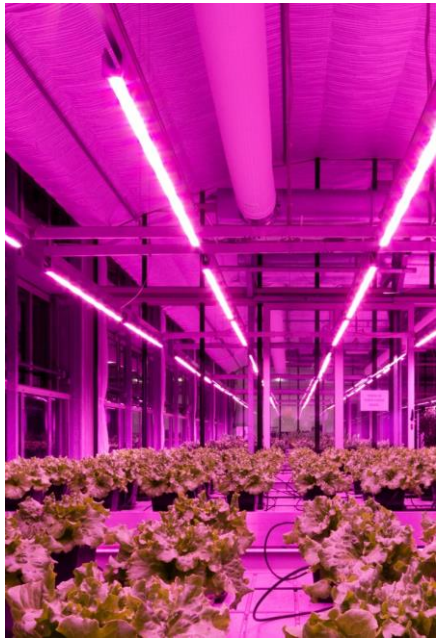
- Lighting technology and Light science
- Industrial design
- Digital Product design
- System prototyping and PoC

MEG concentrates on in-house R&D&I projects aimed to IP generation exploitable for commercialization.

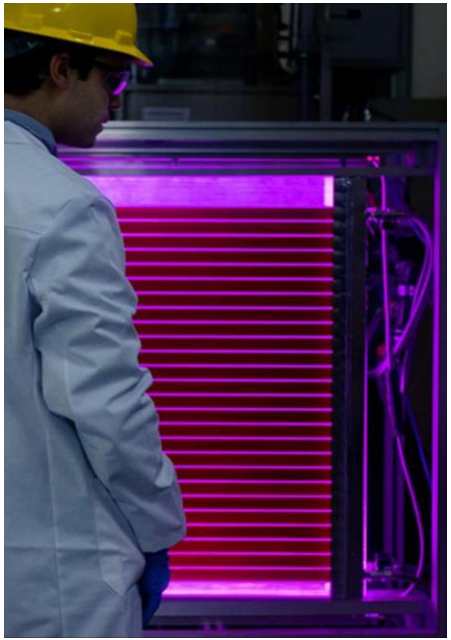
Proprietary PBR LED Panel being tested.

Current areas of work

Our practice applied



Higher plants



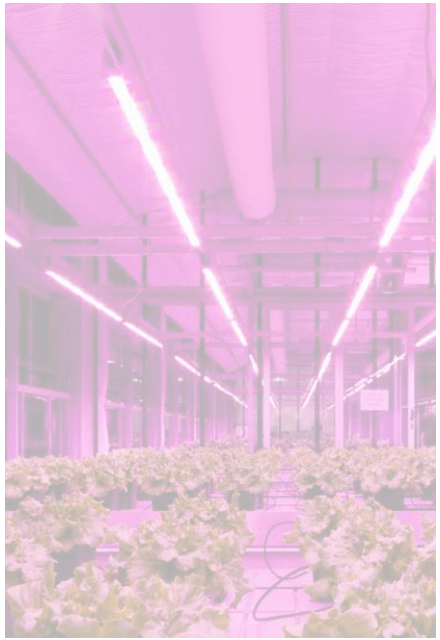
Microalgae

Insects

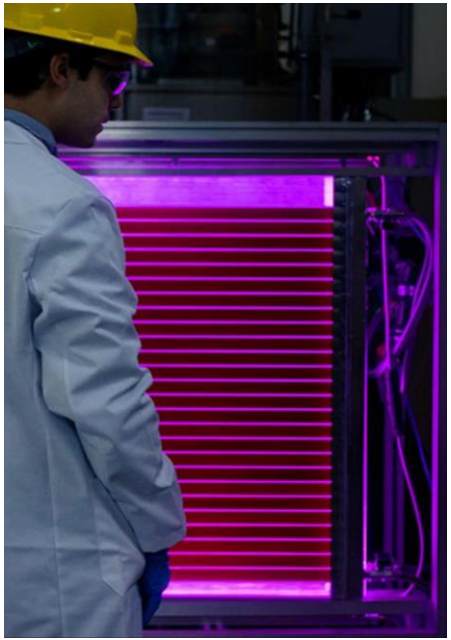
UVGI

Current areas of work

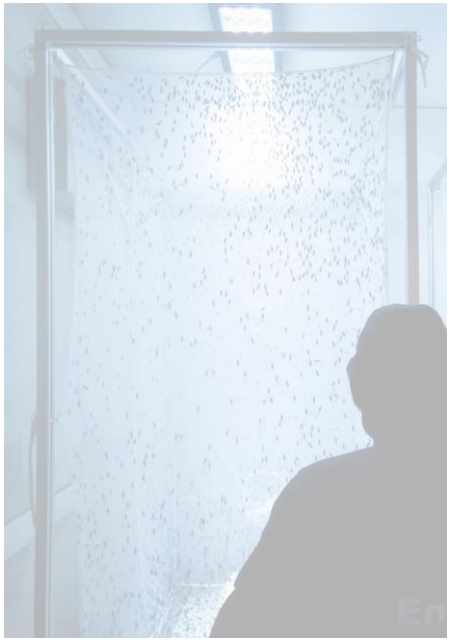
Our practice applied



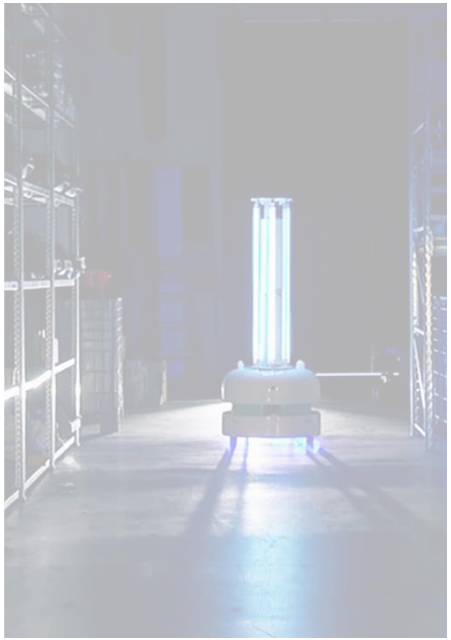
Higher plants



Microalgae



Insects



UVGI

Current areas of work
Our practice applied

We got involved in microalgae and PBR technologies through a practical e theoretical linear path:

- Optimization of Lighting technologies included in existing systems
- Optimization of whole existing systems
- Proprietary technologies development
- Proprietary system development
- Partnership and Licensing

Currently we are developing collaterally scientific knowledge working in connection with key Italian actors :

- Polytechnic University of Turin for microalgae scientific research
- Eni S.p.A. (Oil&Gas Corporate) R&D for carbon dioxide biofixation and high value biomass production

Laboratory vial full of microalgae colture.

Our technology

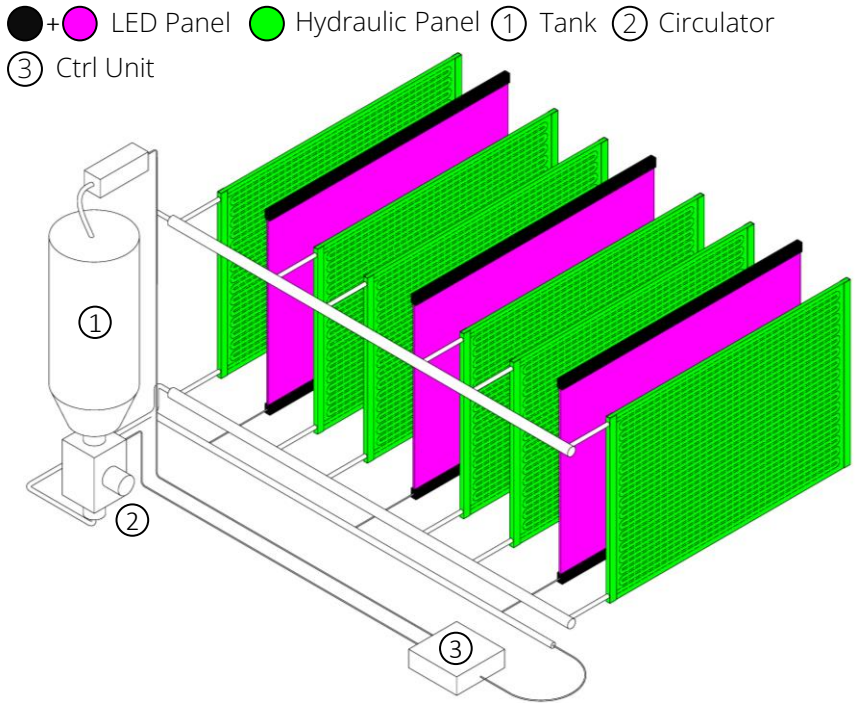
Terrestrial microalgae growth system
Proprietary technology

Stack of different elements designed, tested, validated and patented, currently included in all our PBRs systems (TRL 7).

Composed by an alternated repetition of:

- 2x Hydraulic Panel
- 1x LED Panel

80 mm thick modular sandwich that allows to achieve a **compact footprint** and **high process efficiency**.



Stack functional scheme – Patent WO 2020/104895 A1

LED Panel
Proprietary lighting aspect

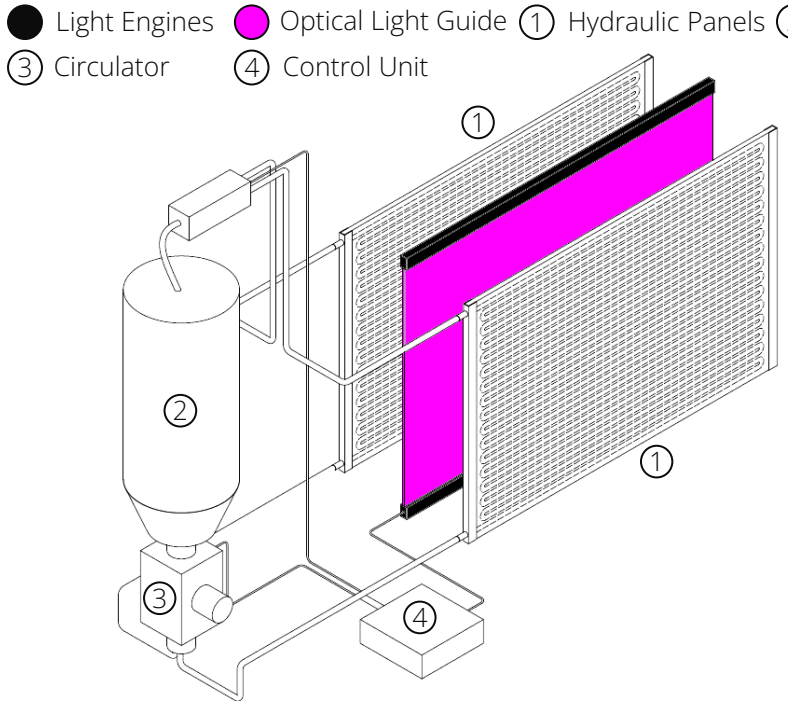
Assembly of two distinct elements:

- 2x Light Engine
- 1x Optical Light Guide

The Light Engines allow to create **taylor-made light spectrum compositions** using up to **12 LED channels.**

The Optical Light Guide allows **efficient bi-lateral light emission** on each Hydraulic Pannel Surface thanks to the optimezed light extraction path.

Everything is characterized by **user-optimized operations** and **optimal thermal management.**



Functional scheme of stack base unit.

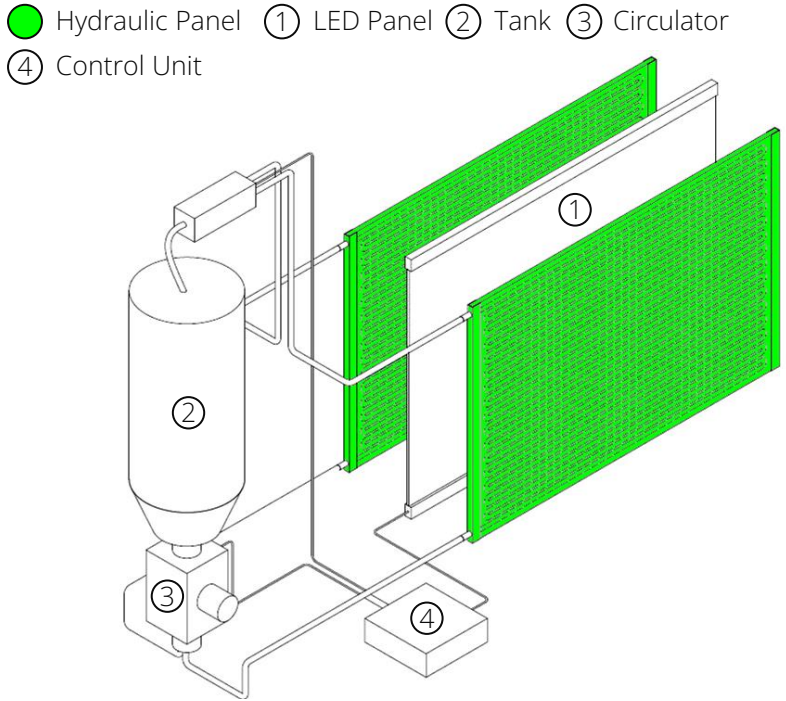
Hydraulic Panel

Proprietary hydraulic aspect

Main hydraulic element of the system, **defines the photo-exposed volume** and **allows the microalgae solution to flow under positive pressure in a flat coil-shaped path.**

Cost effective solution that can contain for each single panel up to **18 liters,** defining a **photo-exposed surface of 1.5 m².**

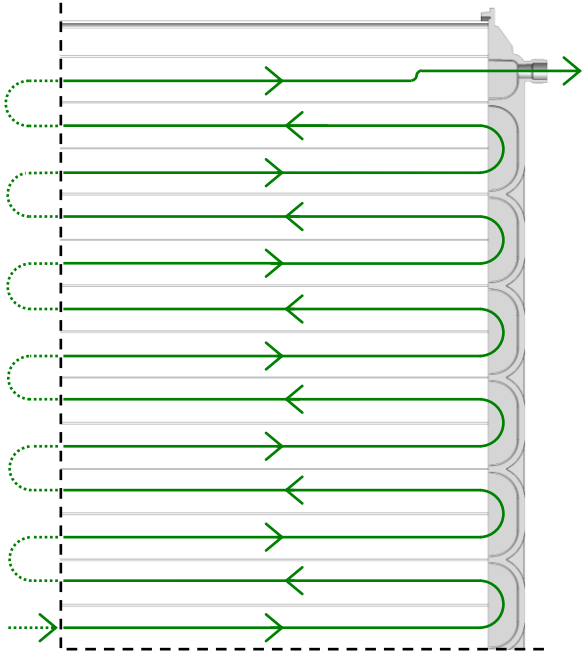
Pressure and operating speed of the internal flow can be adjusted by regulating the circulator.

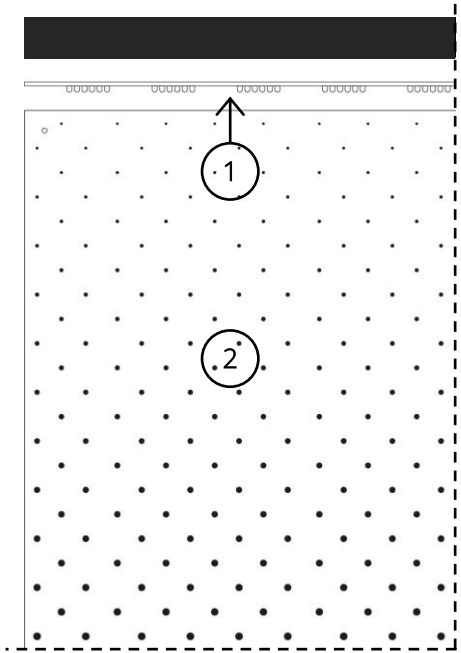


Functional scheme of stack base unit.

Proprietary aspect feature
Distinctive operations details

Microalgae flow path Heat sink ① Light engine ② Optical Light Guide with custom laser etching





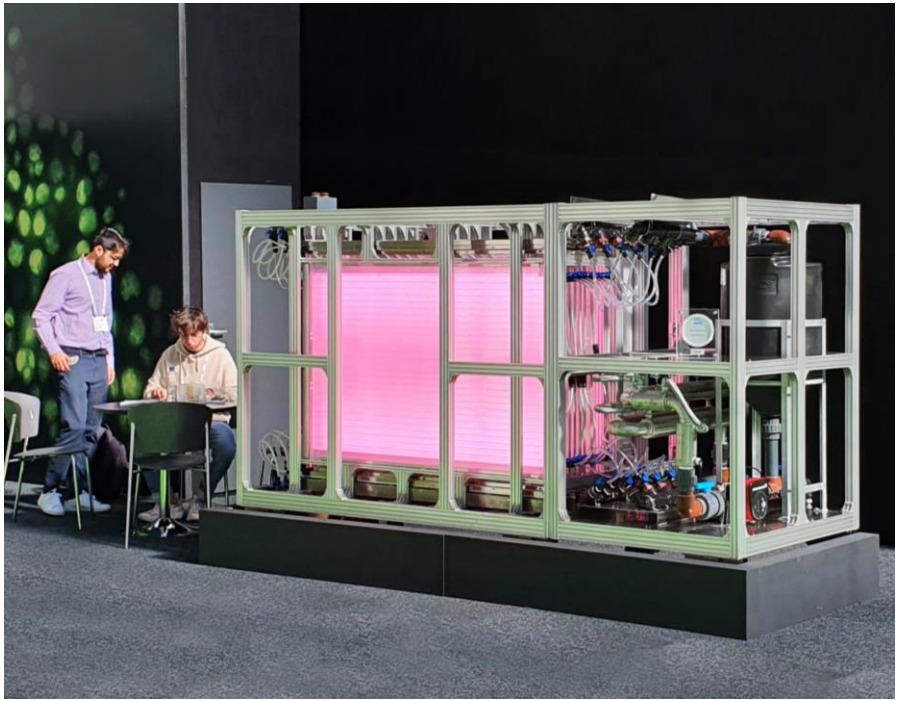
Hydraulic Panel coil-shaped path; LED Panel scheme; proprietary stack detail.

SKID Unit
System description

Working research module for industrial scale PBR plant, tailored for microalgal biomass production, high-value molecules harvesting and carbon dioxide biofixation applications.

- State-of-the-art array of sensors
- Tunable spectrum LED Panels
- Up to 150 liters sized Photo-Loop
- 80 liters sized tank

Currently used by Eni S.p.A as workhorse platform for research focusing on carbon dioxide biofixation and high value biomass production.



SKID Unit – workers for scale.

Phycotrone
System description

Microalgae growth platform for research and laboratory scale applications. It allows its users to perform custom growth sequences, thanks to:

- State-of-the-art array of sensors
- Tunable spectrum LED Panels
- Up to 15 liters sized Photo-Loop
- 15 liters sized tank

Phycotrone gives back key data for:

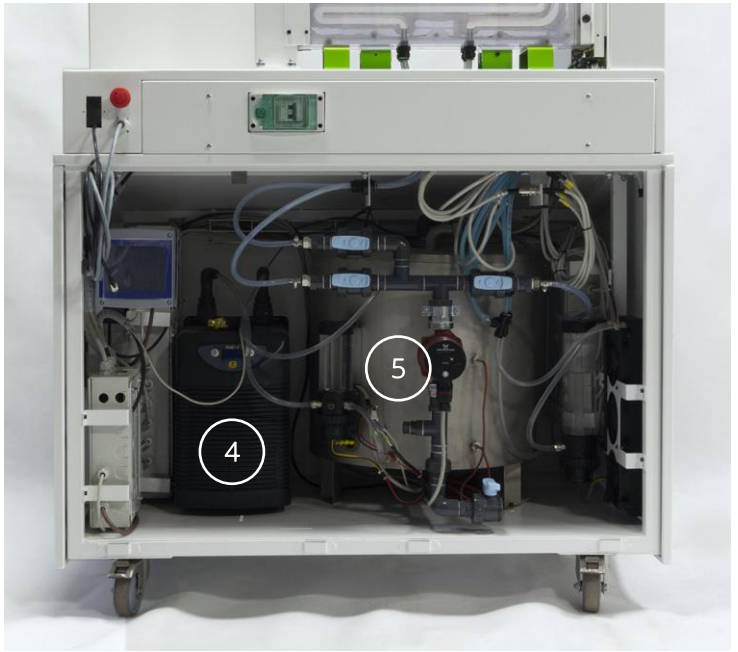
- Parameterisation of microalgal growth sequences
- Testing for industrial-level scale-up
- Stress profiling for high value molecules harvesting

Phycotrone – worker for scale.

Phycotrone
System details

① Sensors ② Hydraulic Panel ③ Microalgae inoculation light box

④ Chiller ⑤ Thermostatically controlled tank



Front worktop; Back machine Internal electronic+electric and hydraulic elements.

Our Vision

Our Vision

What we strive to achieve

Help to face crucial sustainability-oriented food and climate challenges that undermine our shared future on Planet Earth.

Key topic for us are:

- Growing need of food and its security
- Bio-conversion of organic waste
- CO_2 biofixation

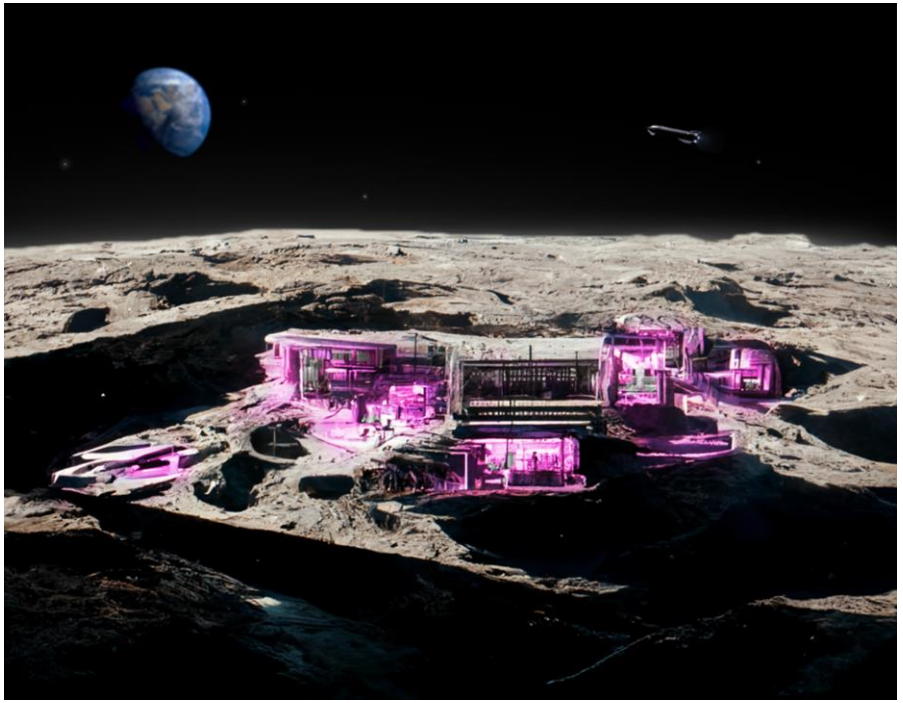
AI generated concept art vision.

Our Vision applied to Space Exploration

How space fit into our practice

We want to be able to support human survival in this new and ongoing chapter of Space Exploration leveraging photobiology systems.

Integrating and developing our technologies and methods, to provide the best experience of living far from Earth for the scientists, tourists and space workers of today and tomorrow.



AI generated concept art vision.

How can we get to that point?

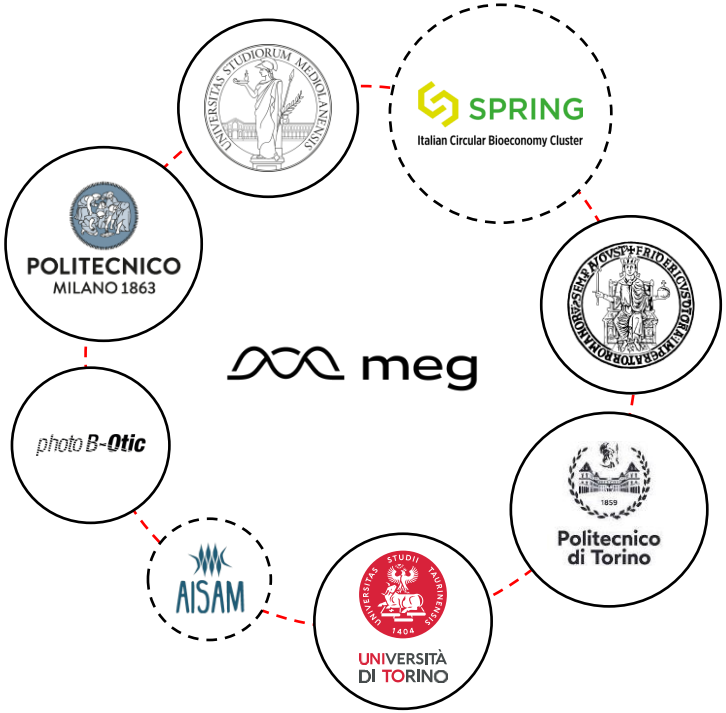
Experimental Project

Research & Development & Innovation without boundaries

Exploration practice aimed to applied lighting technology innovation, research ventures that involves numerous stakeholders from scientific and technical university and private industries.

Core idea of this practice is to leverage individual expertise to achieve complex and multidisciplinary goals – otherwise impossible to reach. Some of key partners have been:

- Polytechnic University of Milan
- Polytechnic University of Turin
- University of Milan
- University of Turin
- University of Naples Federico II
- Photo B-Otic
- AISAM - Italian Association for Microalgae Study & Application
- SPRING Cluster – Italian Circular Bioeconomy Cluster



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PBRSpace

meg + POLITECNICO MILANO 1863

w/additional support from:

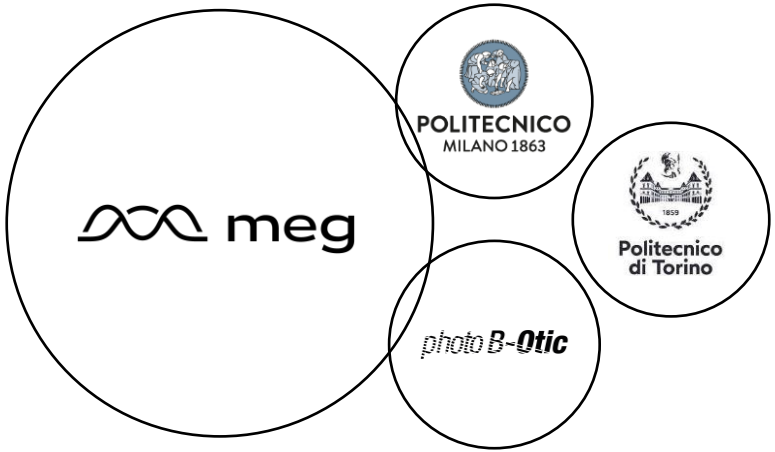
Politecnico di Torino
Department of Environment, Land and Infrastructure Engineering
+ photoB-Otic

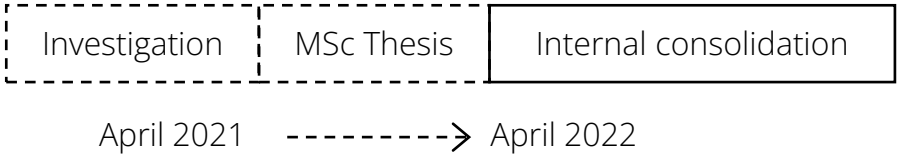
Development path
Step 0: Timeframe and stakeholders

The project started in April 2021 as a collaboration between a multitude of entities:

- **MEG Science** focused on the PBR and the integrated lighting technology
- **Polytechnic University of Milan** provided workforce and expertise for industrial + interaction + system design and project management
- **Photo B-Otic and Politecnico di Torino** provided biological insight and microalgae-related know-how

As first milestone all the work has been published in April 2022 as a MSc Thesis, consolidating furthermore the relationship between the tree parties.



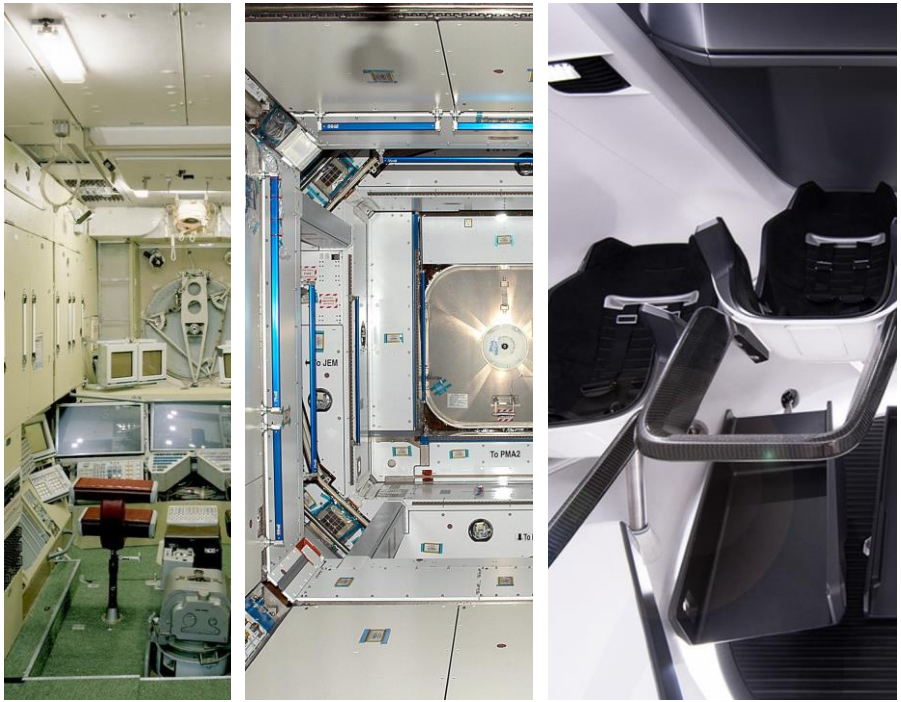


Development path
Step 1: Cultural-historical background research

Research aimed **to understand the role of the Design discipline in Space Exploration Industry.**

Breakdown of its history into **a chapter-based framework to highlight the evolution and integration of the designer's meta-design and design activities over the ages of:**

- Competition between Nations
- Collaboration between Nations
- Diversification between Corporations



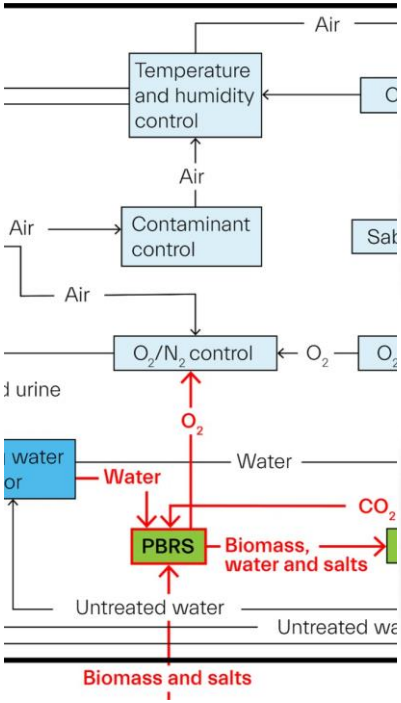
Interior and product design views from the three Space Exploration chapters.

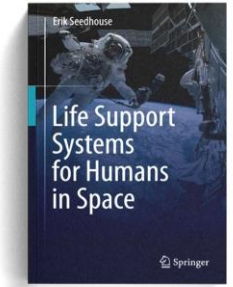
Development path
Step 2: Technical-scientifical background

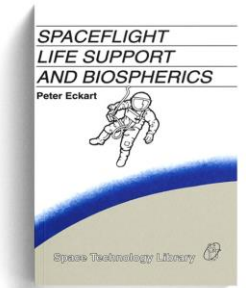
Research aimed at **deepening the state of the art of photobioreactor technologies for space applications** and Life Support Systems to establish a **solid knowledge base.**

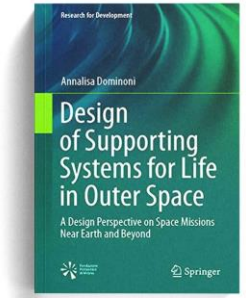
The following were considered:

- Scientific papers
- Academic publications
- ESA + NASA handbooks
- Technology demonstrators









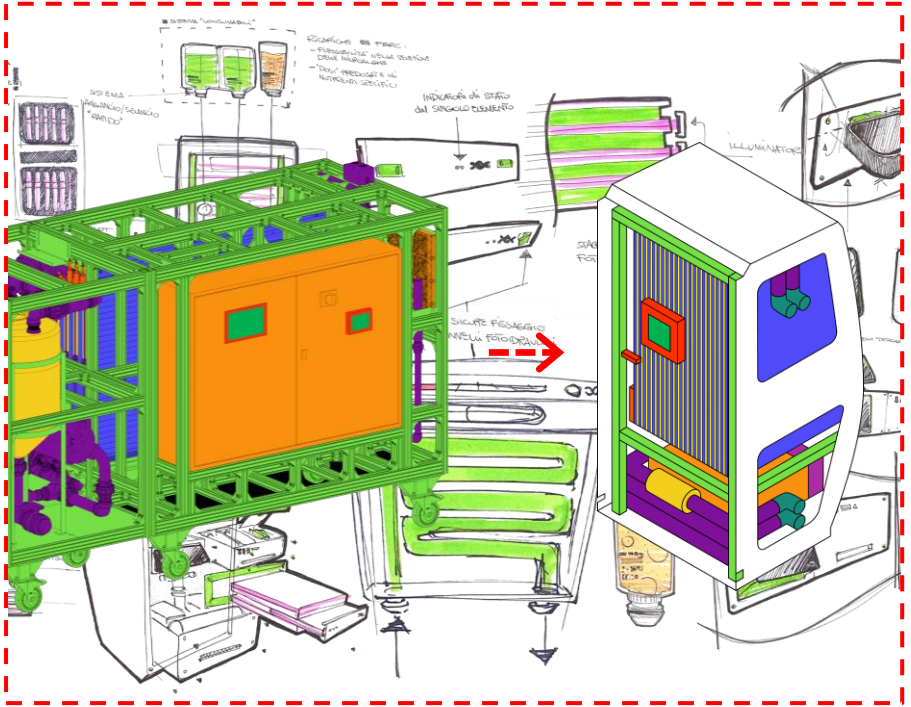
Scope of works detail (adapted from Yang et al. 2019); selected bibliography.

Development path
Step 3: Design

True and central phase of Design-driven Technology Translation.

The project phase merged the two previous researches, making them converge in the definition of novel formal, interaction and feedback elements, in addition to the necessary and central design of the system.

Constant attention was paid to the constraints of architecture and context, plus industry standards.



Technology translation diagram and design sketch composition.

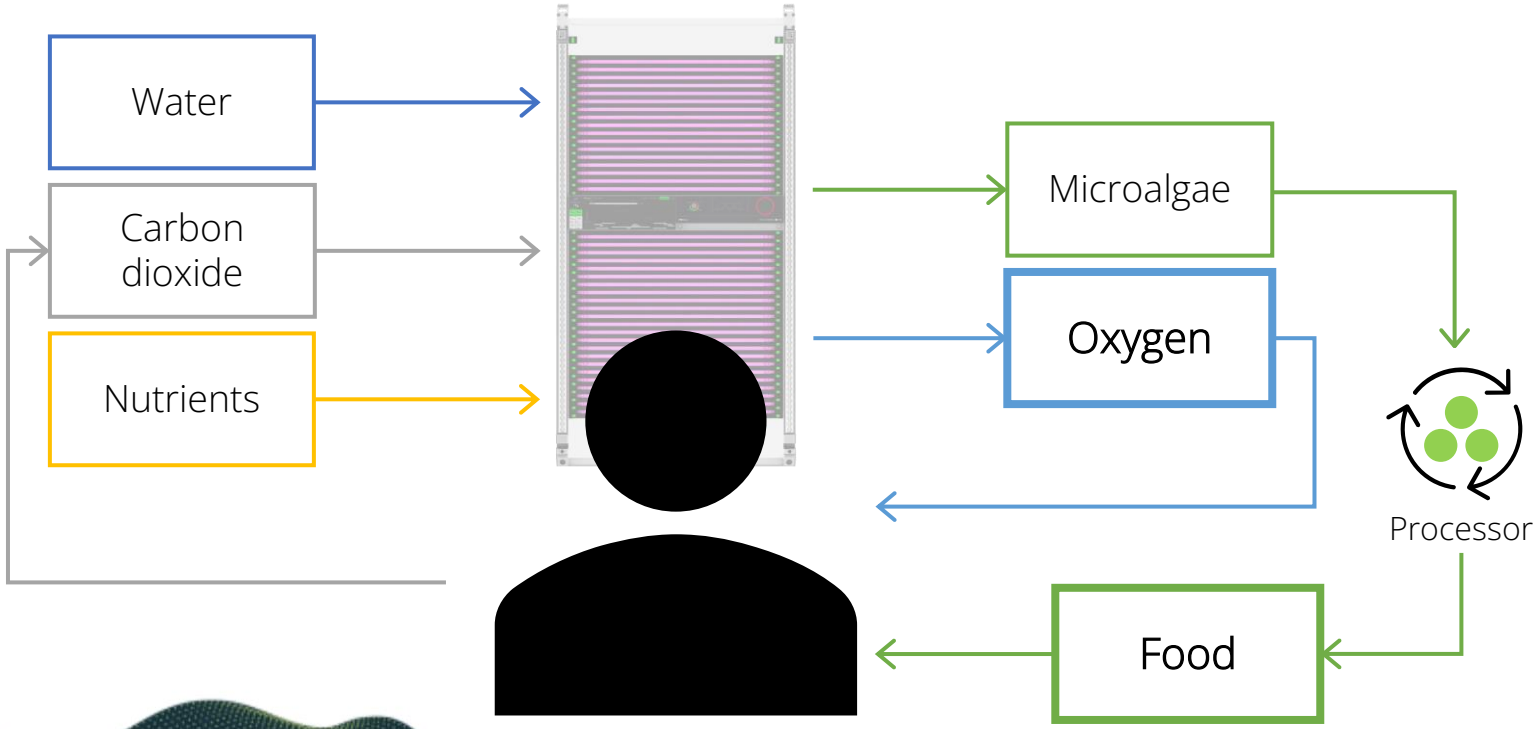
What it is
Scope of work

Advanced photobioreactor concept, **hybrid subsystem for atmosphere regeneration** and **novel subsystem for microalgal biomass growth** – transformable into food and other byproducts – **integrated into a Bio Life Support System architecture for space exploration.**

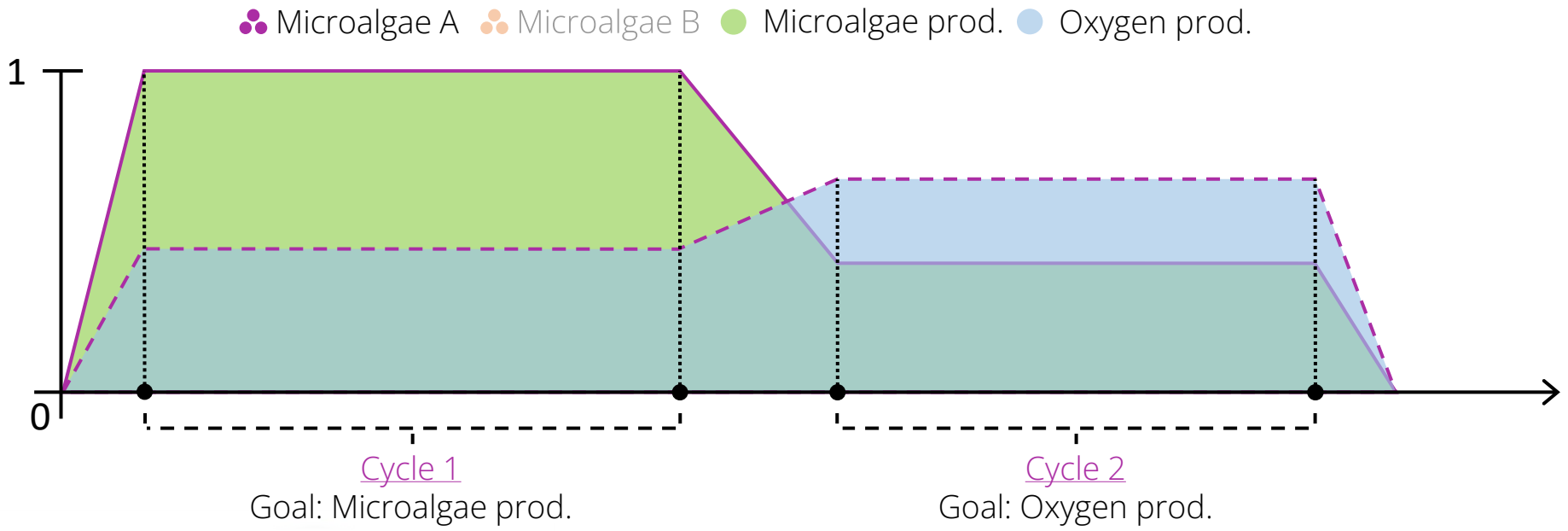
PBRSpace – astronaut for scale.

What it does

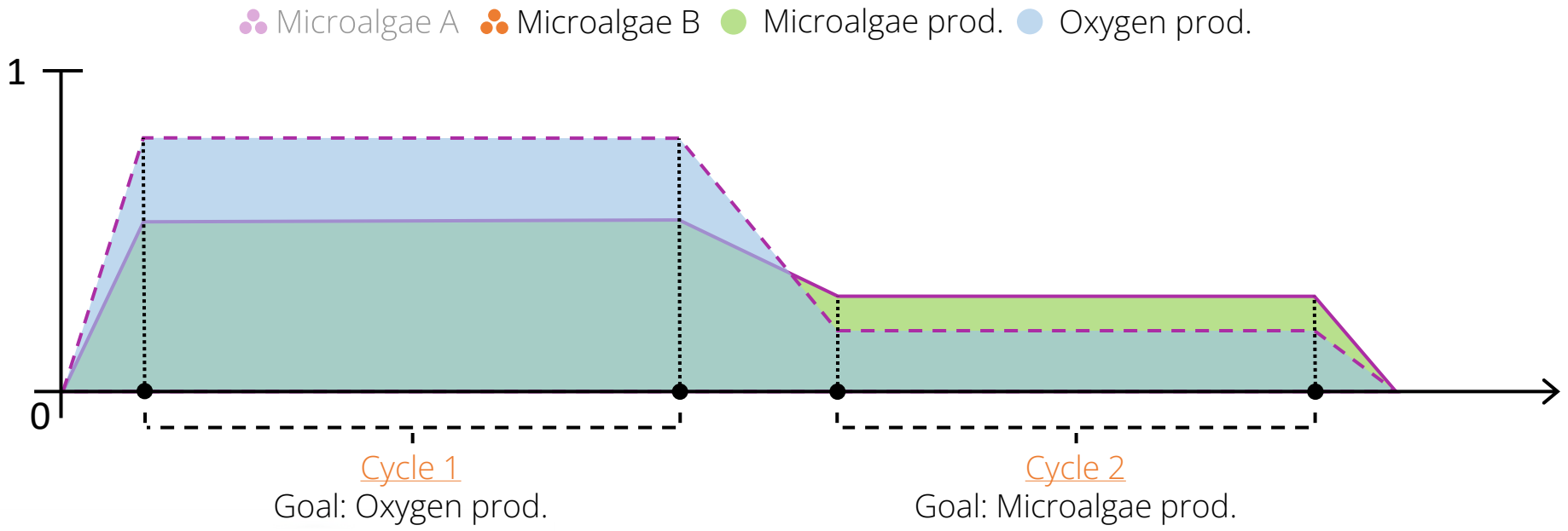
Microalgal biomass + oxygen production



How it works
Hybrid outcomes

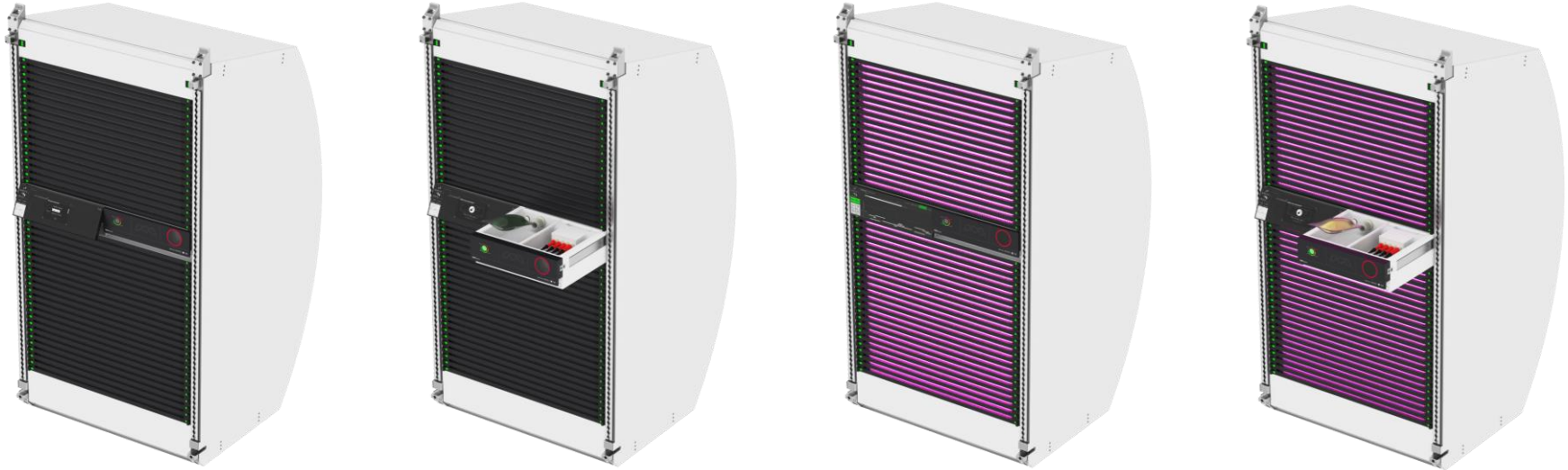


How it works
Hybrid outcomes



How it works

Optimized user operations as design driver



1. Start-up and recipe selection → 2. Microalgae loading → 3. Growth → 4. Nutrients loading

3. Growth → 4. Nutrients loading (loop)

Linear — Loop

Main System Components
Core technologies

Technological stack composed by the coupling of two base element:

- Photo-Hydraulic Panels
- Frontal Light Engines

Together they compose the **photo-exposed section** of the hydraulic aspect of PBRSpace, **where microalgae growth takes place.**

Main System Components
Core technologies

① Frontal Light Engines ② Photo-Hydraulic Panels

Core Technology exploded view; Frontal Light Engine and Photo-Hydraulic disassembly; detail.

Main System Components
Utility Tray and Consumables

Physical and visual interaction point for the loading of the two system consumables:

- Microalgae inoculums
- Nutrients

Indicator light and **Microalgae Window** provide the user with direct visual feedback on the Utility Tray operation a status, plus microalgae health.

Lorem ipsum dolor sit amet, consectetur adipiscing elit.

① Circulators ② Microalgae Inoculum ③ Sensors ④ Cables + tubes ⑤ Indicator Light ⑥ Microalgae window

Utility Tray exploded view; detail.

Main System Components

Digital Panel + Digital lambda

Digital control point of PBRSpace operation.

The **Digital Panel** is a physical interface **for human-machine interaction, Digital λ** is the **software** included in the system **for controlling the microalgal growth.**

Main System Components
Digital Panel + Digital lambda

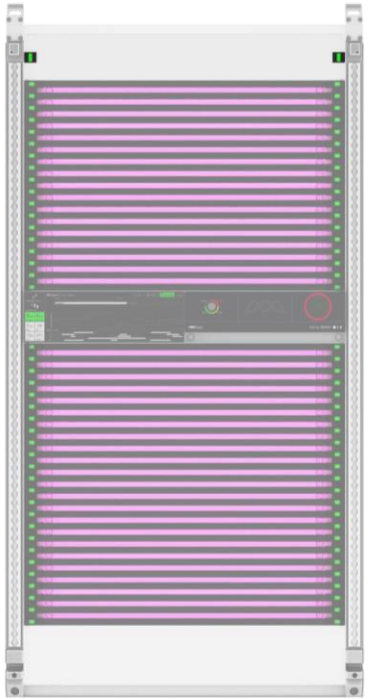
Digital Panel and software Digital λ details.

Main System Components
Degassing system

Technological assembly for **concentrating and redirecting the oxygen** generated by microalgal growth.

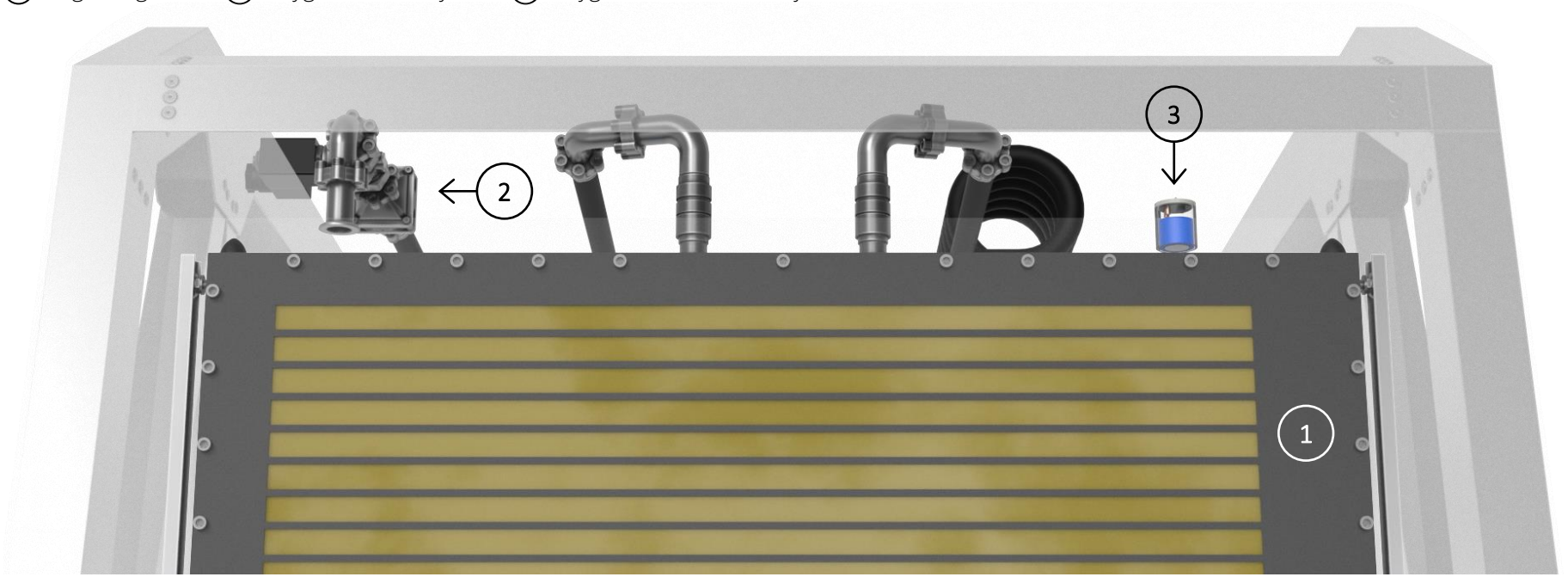
It includes

- Degassing Panel
- Oxygen concentration sensors
- Oxygen Suction system



Main System Components
Degassing system

① Degassing Panel ② Oxygen suction system ③ Oxygen concentration system



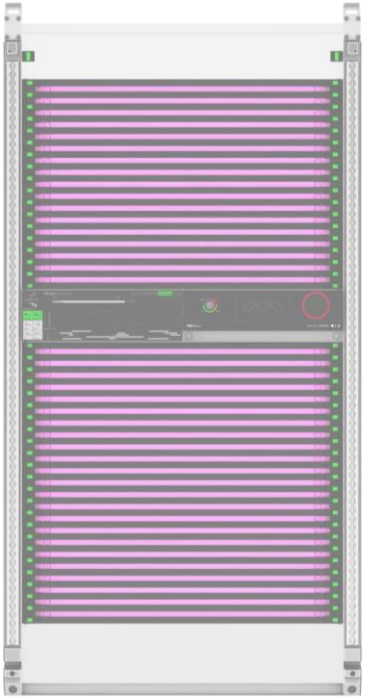
Degassing System detail - ISPR racks in fade.

Main System Components
Service drawer

Access point for technical elements maintenance, such as:

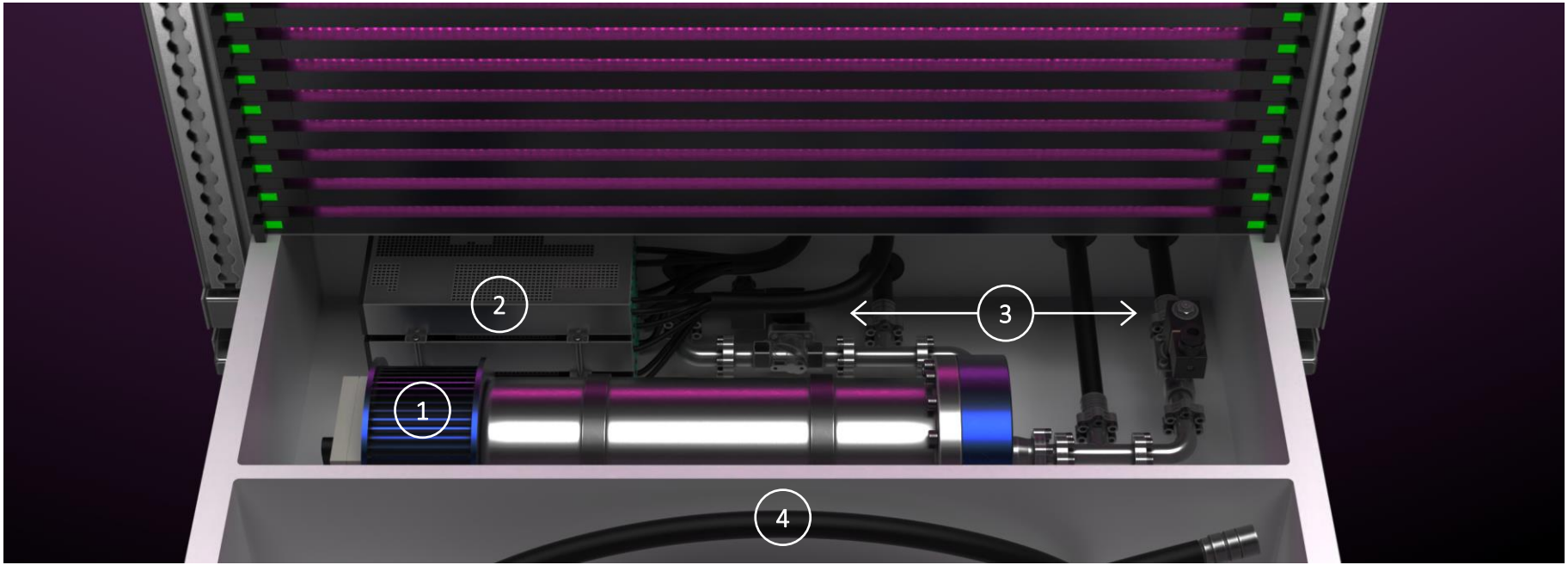
- Main Hydraulic Circulator
- Power supplies
- Solenoid valves for inlet/outlet control

Also stores the Suction Hose, dedicated tool for Photo-Hydraulic Panels maintenance.



Main System Components
Service drawer

① Main Hydraulic Circulator ② Power supplies ③ Solenoid valves ④ Suction Hose



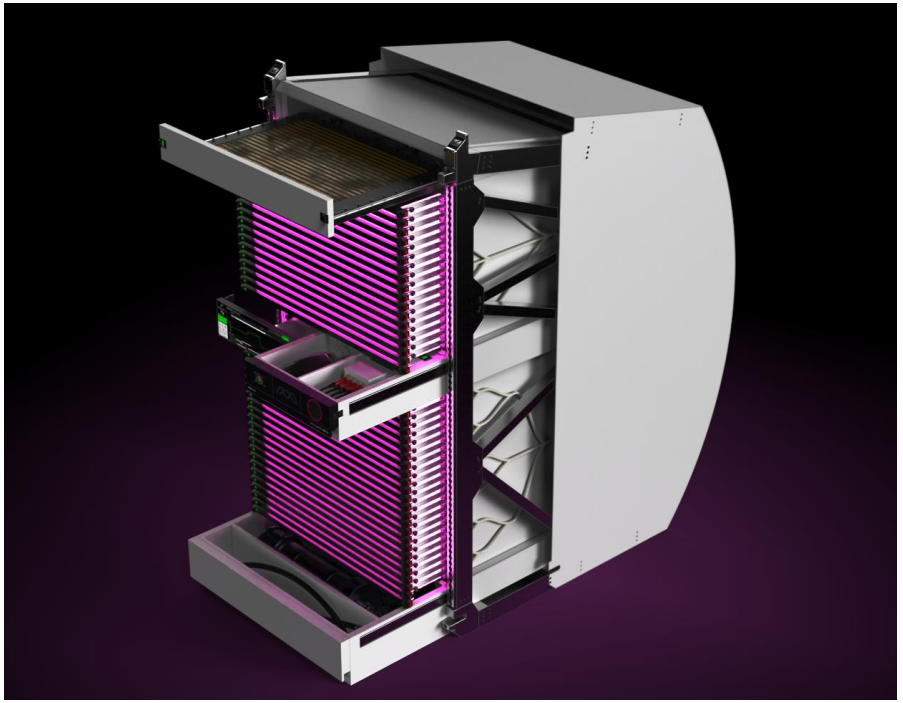
Service drawer detail.

How is this journey going?

Goals

What we achieved through this journey

- Internal validation of PBR → BLSS integration
- Specific literature primer definition for future developments
- Technology translation of our proprietary technology Earth → Space
- “ISPR-ready” development path
- Definition of novel elements with respect to shapes, interaction and feedback compatible with the space environment.



Partial exploded view of PBRSpace.

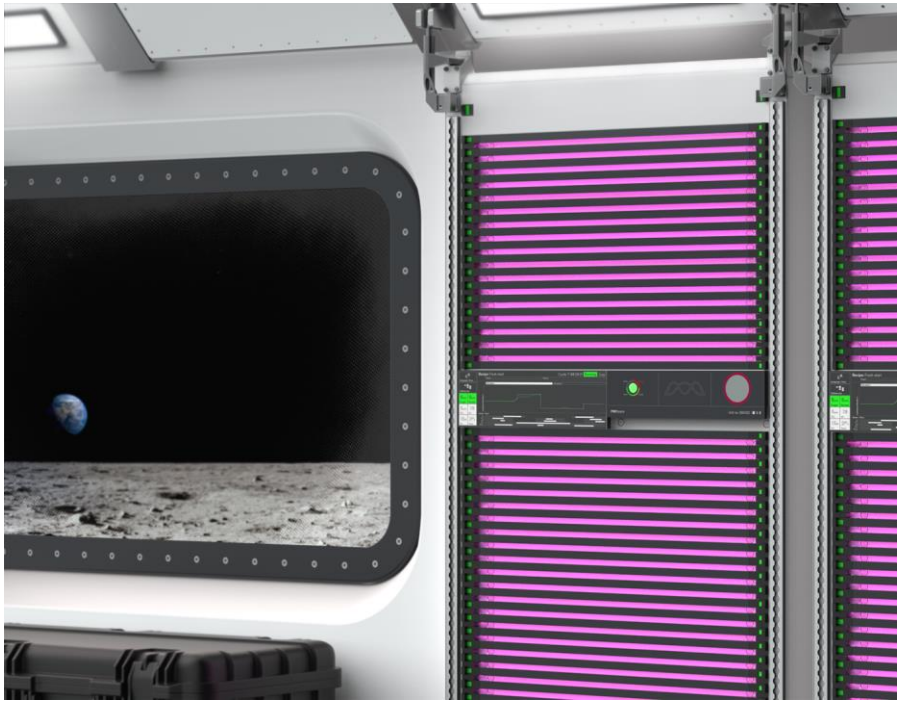
Next goals
Future key-phases and stakeholders

We are new in the space sector but not in solving challenges through innovative solutions.

Confident to find out our “space” of cooperation in such a challenging and stimulating environment.

In order to achieve this, we want to:

- Establish cooperation with new synergic and complementary stakeholders to advance in TRL status
- Shape and participate in collaborative R&D&I projects in the framework of EU funding programs and other opportunities to accelerate the scaling-up of the Technology. Any suggestion is welcome!



PBRSpace systems integrated into a future Lunar Outpost.

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THANK YOU.

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