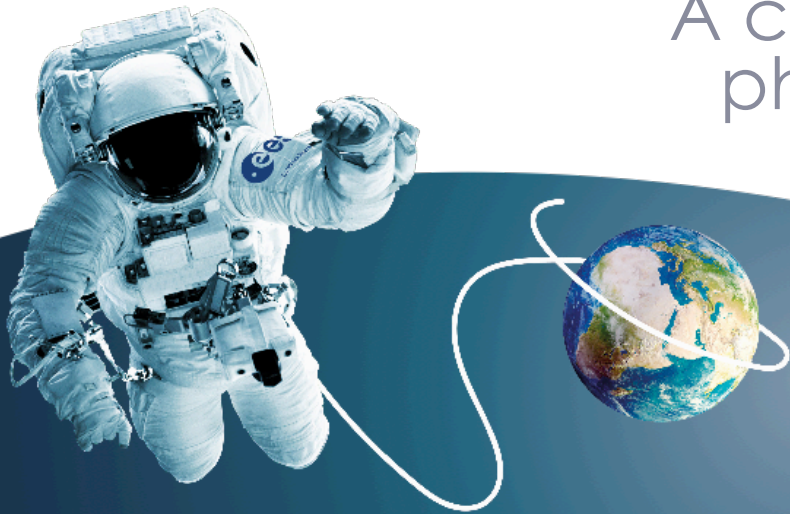




PRIAM :

A compact intensified artificial light photobioreactor adapted to life support for human space exploration



THOBIE C., PERUCHON L., PRUVOST J. BROCHIER C.



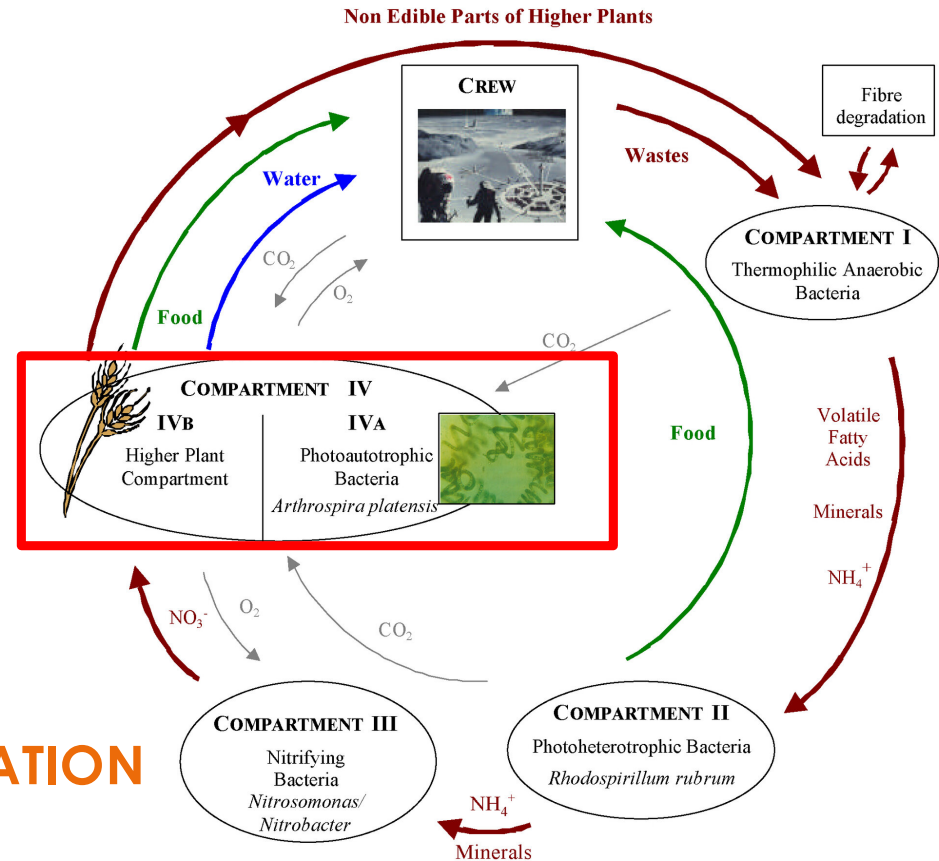


1- Context : Photobioreactors for A life support For the human space exploration

COMPARTMENT IV a - MAIN OBJECTIVES :

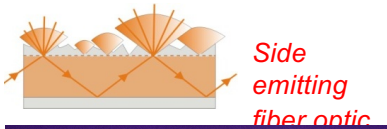
- ❑ Used to answer the problem of the atmosphere regeneration → **produces oxygen and fixes CO₂**.
- ❑ Used to the food production → micro-organism **edible, enough biomass**
- ❑ Used to the liquid waste treatment.
- ❑ One of the main constraints to cultivate microorganisms in space is that it is necessary to produce **sufficient food in a restricted place**

→ **SOLUTION : PHOTOBIOREACTOR INTENSIFICATION**





1- Context : LIGHTEX® technology – Luminous technical fabrics made of optical fiber from lighting to photosynthesis

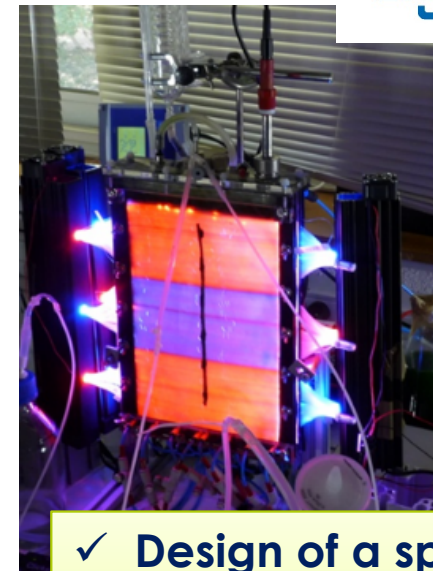


BROCHIER® TECHNOLOGIES

Lightex® technology from :

- ❑ Weaving of optical fibers on a Jacquard loom
- ❑ Treatment of optical fiber surfaces for lateral lighting
- ❑ Coupling of optical fiber bundles with light sources (LED)
- ❑ Controlling and powering LEDs

Lightex®

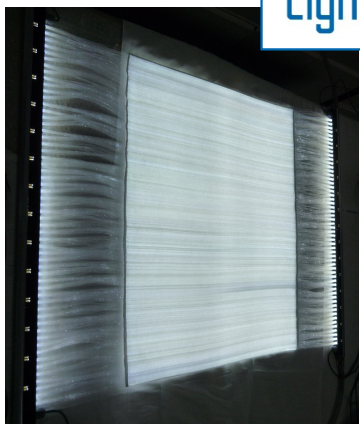


- ✓ Design of a specific fabric for photosynthesis application
- ✓ 1st mock-up (2010)

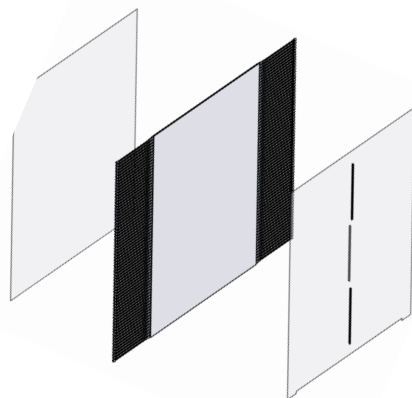


2- PRIAM Prototype : Photobioreactor made of multilayer of LIGHTEX® / Luminous fiber optic fabric

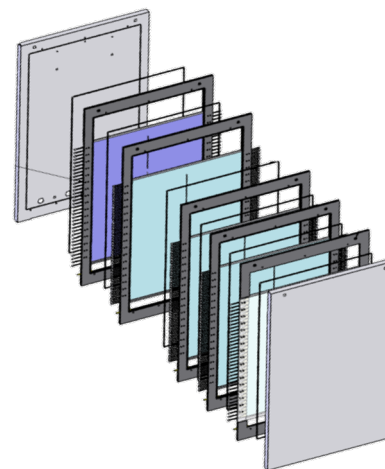
Based on a Lightex® bright double-sided panel, a plane photobioreactor with internal volumetric illumination – PRIAM, has been developed in cooperation with University of Nantes.



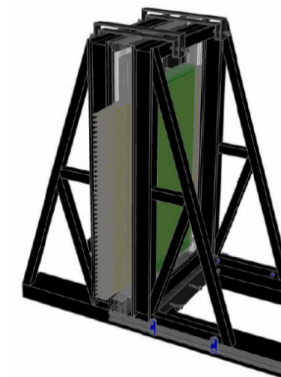
h ν emission
 $205 \pm 25 \mu\text{mol m}^{-2} \text{s}^{-1}$



Lightex® panel
between 2 polymer
plates



Multilayer stack of Lightex
plates illuminating culture
chambers



Innovative
PRIAM PBR
(2015)

Patented PBR technology





2- PRIAM : A breakthrough photobioreactor with internal illumination for a high volumetric illumination for a very high productivity



PRE-INDUSTRIAL SYSTEM (2018)



Continuous productivity
3.75 kg m⁻³ day⁻¹

No biofilm !!

PRIAM PROTOTYPE :

- ❑ floor area : 1 m²
- ❑ height : 2 m
- ❑ specific light area : ~500 m²/ m³
- ❑ liquid volume : ~10 liters (5 panels)
- ❑ in situ control of pH, temperature, ...

- ❑ closed system in a **sterile environment**
 - ❑ **cGMP** production of microalgae
 - ❑ **modular design**
- To our knowledge : no equivalent system

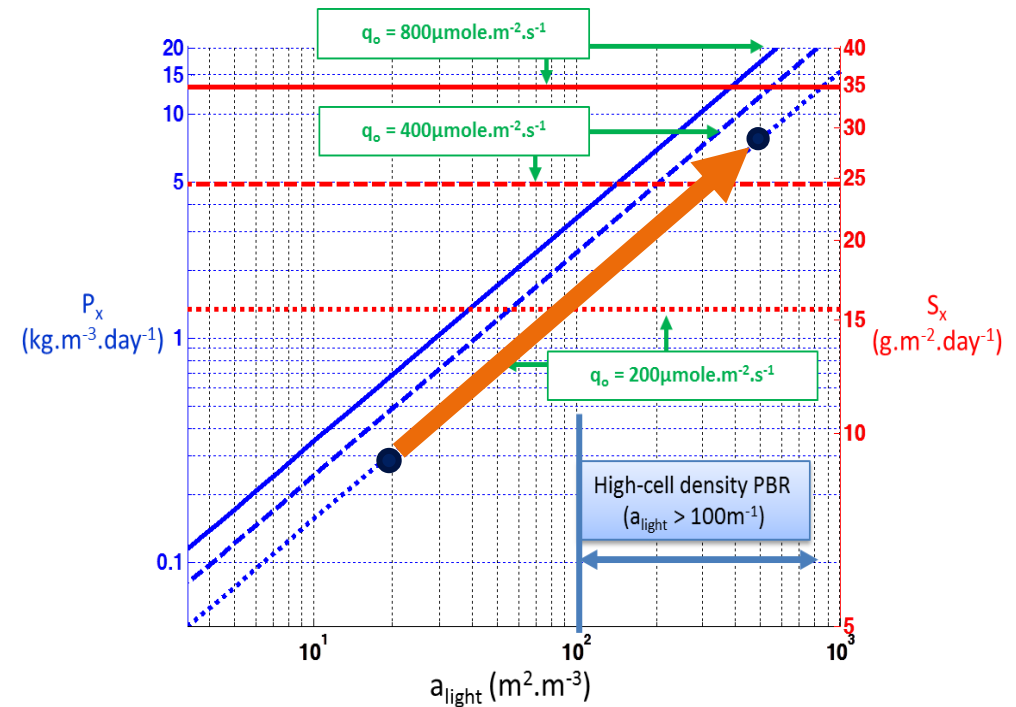


3- Technology positioning

PRIAM is a breakthrough intensified culture technology suitable for **controlled, industrial, and artificial light cultivation**

The productivity of photobioreactors is driven by three main parameters of engineering:

- Incident flux receives (PFD, q_0)
- **Illuminated surface area ($a_{light} = S/V$)**
- Unlit design volume ($fd = 0$ often)



PRIAM is a breakthrough intensified culture technology suitable for **controlled, industrial, and artificial light cultivation**

Technology	Illuminated surface area a_s	Production volume	Maximum volume Productivity (kg/m ³ /d)	Daily biomass production range (kg / d)
HECTOR (<i>C. Vulgaris</i>)	18 m ² .m ⁻³	130 litres	0,13	0,017
XANTHELLA (<i>A. platensis</i>)	≈ 10 m ² .m ⁻³	12*1 m ³	0,1-0,3	2,4
FPA – SUBITEC (<i>Haematococcus</i>)		4*27,5L = 110L	0,4	0,044
PBR-PRIAM (prototype) (<i>C. Vulgaris</i>)	496 m².m⁻³ (e = 3 mm)	≈10L	3,7	0,035-0,039
PBR-PRIAM (industriel)	496 m².m⁻³ (e = 3 mm)	1m ³	3,7	3,5-3,9



➔ **Gain in volume productivity between 15 and 30 & Modular production**

Volume = 1m³
Daily production : 3.5-3.9kg/jour



No equivalent today ...

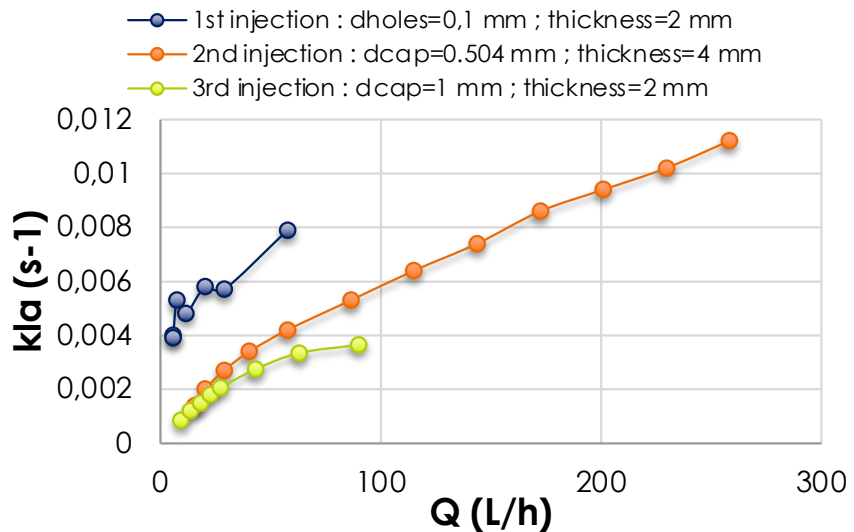
MELISSA 4- Main issues in intensified technologies

Low culture thickness

Increase in culture viscosity at high cell concentration. Or even non-Newtonian behavior.

One of the major obstacles of intensified PBRs: HYDRODYNAMICS

PRIAM : Bubbling optimization

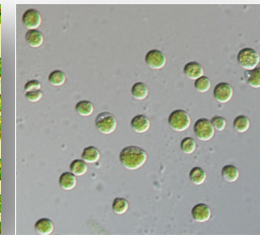
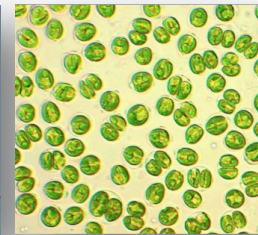
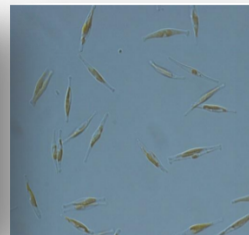
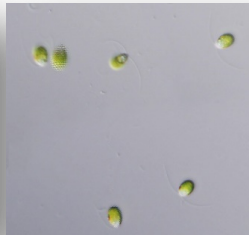
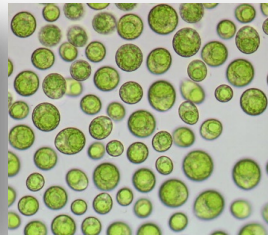
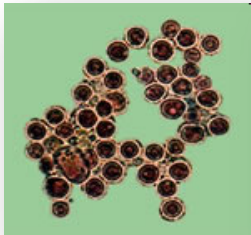


Control of gas-liquid transfer (non-limiting CO₂ + no accumulation of O₂)

Culture management (homogeneous culture, no biofilm, etc.)

Photosynthetic microorganisms :

- Porphyridium cruentum*
- Chlamydomonas reinhardtii*
- Dunaliella salina*
- Phaeodactylum tricronutum*
- Tetraselmis suecica*
- Chlorella Vulgaris*





5- Performance obtained in PRIAM - Optimization of light spectrum and hydrodynamics

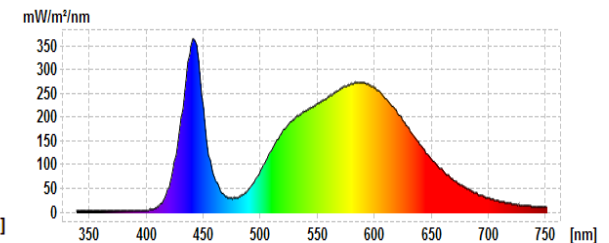
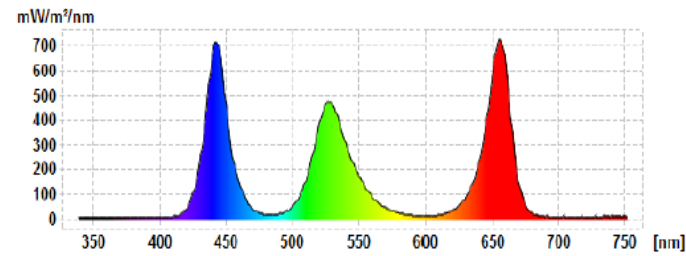


Technology PRIAM uses LEDs : light spectrum can be adapted to the microalgae and the metabolites of interest that we want to produce



Hydrodynamic optimization

Bleu, vert et rouge



Mesures	
Radiometric (mW/m²)	50867.39
PPFD (µmol/m²/s)	229



Increased productivity of some metabolites of interest



6- Algolight start-up



PRODUCE HIGH-VALUE METABOLITES FROM PHOTOSYNTHETIC MICROALGAE AND CYANOBACTERIA IN A CLOSED, **COMPACT, CONTROLLED, STERILE SYSTEM !**



NOW



Interesting metabolites ?

Pharmaco-active metabolites:

- *anti-viral, anti-cancer, anti-bacteria, anti-inflammatory,*
- *neuro-protectant, ...*

Toxic metabolites:

- *bioactives, veterinary products, pest control,....*

Recombinant proteins? GMO microalgae?

Life support for human space exploration?

Other??

MELISSA



MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
ALTERNATIVE

THANK YOU.

THOBIE Charlène

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