

## Scientific achievement #5

### MELiSSA: the European Bioregenerative Life Support System project

MELiSSA (Micro Ecological Life Support System Alternative) has been conceived as an ecosystem based on microorganisms and higher plants, intended as a tool to gain understanding of the behaviour of artificial ecosystems. This concerns the development of technologies for a future biological life support system (BLSS) for long term manned space missions, e.g. a lunar/Mars bases or missions. Initiated in 1989, this European Space Agency (ESA) program is the leading Closed Ecological Life Support Systems (CELSS) European project. It involves ten teams in Europe and Canada. Since the beginning, GePEB group has a significant contribution for supporting the chemical engineering approach of the project, especially for bioreactor engineering: (i) cultivation, analysis, balances analysis in bioreactor; (ii) modelling by mechanistic approach at multi-scale level; (iii) High performance photobioreactors engineering.

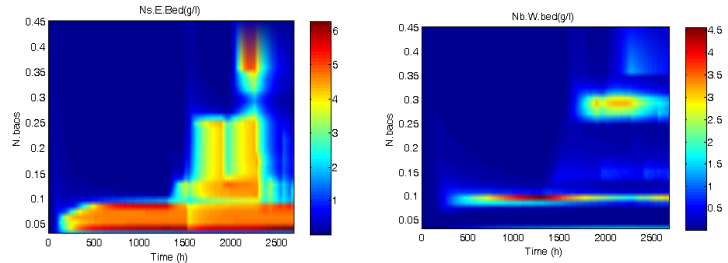
MELiSSA project is one of the few CELSS developed in the world as a part of Environmental Control and Life Support Systems (ECLSS). The ECLSS consists of an air revitalization system, water coolant loop systems, atmosphere revitalization pressure control system, active thermal control system, supply water and waste water system, waste collection system and airlock support system. These systems interact to provide a habitable environment for the (space) flight crew in the crew compartment in addition to cooling or heating various orbiter systems or components. The driving element of MELiSSA is the recovering of food, water and oxygen from waste (feces, urea), carbon dioxide and minerals. Based on the principle of an "aquatic" ecosystem, MELiSSA is comprised of 5 main compartments (figure 1) colonised respectively by thermophilic anoxygenic bacteria, photoheterotrophic bacteria, nitrifying bacteria, photosynthetic bacteria, higher plants, and the crew. MELiSSA is a collaborative project managed by ESA and involving several independent organisations: University of Ghent, University of Mons (B), University Blaise Pascal (GePEB) (F), SHERPA (F), SCK (B), VITO (B), University Autònoma de Barcelona (E) and University of Guelph (CDN). It is co-funded by ESA, the MELiSSA partners, and several European delegations.

Since the beginning of MELiSSA, GePEB has been involved in the 3 main phases of the project.

Phase 1 - basic research and development: the contribution of GePEB covers all the compartments of the MELiSSA loop. This concerns the analysis and the modelling of the compartments (bioreactors) and of the complete loop (feasibility, degree of freedom and ECLSS scenario) from a metabolic level scale up to the bioprocess scale.

Both microbiological and physical processes

Fig. 2: Compartment 3 (nitrifying Packed Bed Reactor) modeling. Result of the distribution of the fixed biomasses of *N. Europeae* and *Nb. Winogradskyi* on the fixed bed during a 120 days continuous culture.



and bottlenecks were considered allowing the development of mechanistic models suitable for predictive control. This is used for design and for scale-up of the bioreactors. Obviously the tuning and validation of the models have required to performed lab-scale experiments (1 to 5-Litre bioreactors). The most relevant results obtained are illustrated by: (i) photobioreactor model (associated to a light diffusion model) used as well for control and for designing pilot scale photobioreactor (figure 1); (ii) nitrifying packed-bed model predicting non measurable variables such as fixed biomass distribution (figure 2). Current studies at GePEB deals also with higher plant growth chambers and interaction between plant growth and environmental conditions (gravity, humidity, etc.)

Phase 2 - preliminary Flight experiments: GePEB was involved in flight experiments projects such as: (i) design of a microgravity membrane photobioreactor for the study of the growth of *A. platensis*; (ii) design of an experiment for the validation of the

atmosphere control ( $O_2$  production /  $CO_2$  removal) in a coupled animal compartment / photobioreactor (BioRat project).

Phase 3 - ground and space demonstration: as photobioreactor and model experts in the MELiSSA group, GePEB is associated to the development of the MELiSSA Pilot Plant (MPP) assembled in Universitat Autònoma de Barcelona. Basically, MPP is sized for fulfilling 100% of atmosphere, 100% of water and 20% of food for 1 man.

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#### FURTHER READING

*Axenic Cultures of Nitrosomonas europaea and Nitrobacter winogradskyi in Autotrophic Conditions: a New Protocol for Kinetic Studies*  
B. Farges et al., Applied Biochemistry and Biotechnology 167, 1076 (2012)

*Study of mass transfer by condensation in humid air for life support systems*  
A. Tiwari et al., Proceeding of ICES-2012, AIAA, 3562 (2012)

*Knowledge models for the engineering and optimization of photobioreactors*  
J. Pruvost et al., in : *Microalgal Biotechnology vol.1 "Potential and Production"*, Editeurs: C.Posten and C.Walter, De Gruyter GmbH & Co. KG, Chap. 10, pp. 181-224, ISBN 978-3-11-022501-3

#### CONTRACTS

ITT ESTEC Contract (2010-2015)  
TEC-MMG ESTEC Contract (2014-2016)  
MPP-CNT ESA Contract (2013-2016)

#### PhD

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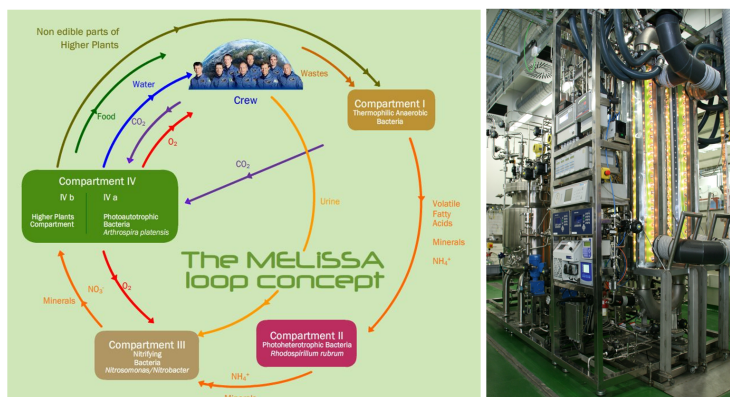


Fig. 1: MELiSSA loop concept: 4 micro-biological compartments (bioreactors) + Higher Plant chamber + crew habitat and MELiSSA 100L compartment 4a (*A. Platensis* photobioreactor) in operation in the MELiSSA Pilot Plant (Universitat Autònoma de Barcelona), designed from GePEB expertise in photobioreactors.