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MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

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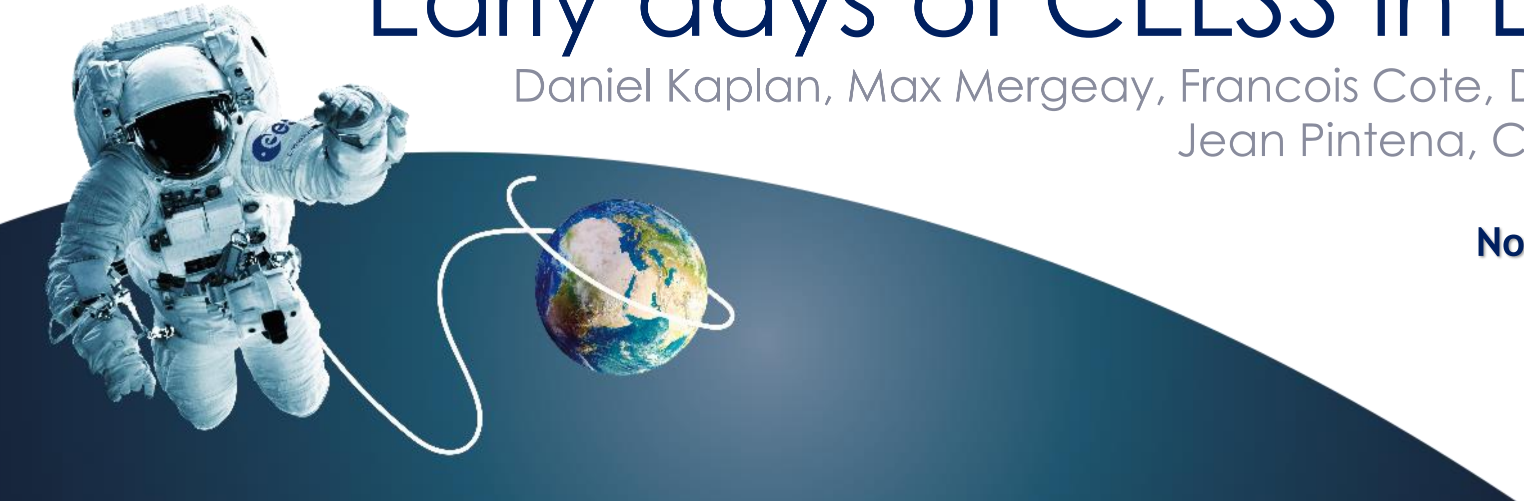
CREATING A CIRCULAR FUTURE

# Early days of CELSS in Europe

Daniel Kaplan, Max Mergeay, Francois Cote, Daniel Massimino, Jean Pintena, Christophe Lasseur

**November 10th, 2022,**



# Disclaimer

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- Although the authors were all actors of these early days, they all have a technical or scientific background, so this presentation has no will to be an historical work.

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# A focal point

Dr R.D. Mac Elroy

Head of CELSS Program

NASA Ames Centre

California

# Back to the 80's

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- As far as identified, the first European document related to CELSS in Europe is from AIRBUS (DORNIER-Germany) dated 1983 and presented to ESA ECLSS and thermal conference. A Concept approach for BLSS.
- No evidence experimental work was initiated.

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# Then, 1985 NASA workshop

NASA TM 88215

## Controlled Ecological Life Support Systems: CELSS '85 Workshop

Edited by:
Robert D. MacElroy, NASA Ames Research Center, Moffett Field, California
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January 1986

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NASA
National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, California 94035

Papers from a workshop held at
the NASA Ames Research Center
Moffett Field, California
July 16-19, 1985

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# 1985 NASA workshop

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European Space Agency

N86-19911 851395

## The $C_23A$ System, an Example of Quantitative Control of Plant Growth Associated with a Data Base

Marcel André,
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and Alain Gerbaud

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ABSTRACT

The architecture of the $C_23A$ (Chambres de Culture Automatique en Atmosphères Artificielles) system for the controlled study of plant physiology is described :

1) Modular plant growth chambers and associated instruments (I.R. $CO_2$ analyser, Mass spectrometer and Chemical analyser).

2) Network of frontal processors controlling this apparatus

3) Central computer for the periodic control and the multiplex work of processors. It also concentrates the data, obtained from processors, and stores them in long term data base.

4) Network of terminal computers able to ask the data base for data processing and modeling .

Examples of present results are given : growth curve analysis, study of $CO_2$ and $O_2$ gas exchanges of shoots and roots and daily evolution of algal photosynthesis and of the pools of dissolved $CO_2$ in sea water.

This system is extremely useful to continue progress in agricultural research. Another application is in Controlled Ecological life Support Systems (CELSS) for space habitats.

The lack of indepth knowledge of plant behaviour becomes both more obvious and more crucial when studying models of whole systems, for example, to predict the long term effect of $CO_2$ increase on vegetation, (1) or to cultivate plants in chambers under totally artificial conditions in complex ecological cycles such as for the Controlled Ecological Life Support System (CELSS) program (2), suggested for the economical habitation of space stations over periods ranging from months to years.

Conversely, studies at the microscopic level have most frequently been initiated, oriented ans stimulated by observation of macroscopical phenomena. That tends to be forgotten and the interest in whole plant studies has decreased, at least in France, to the profit of new areas like molecular biology.

WHAT IS THE CAUSE of this disinterest, in spite of the needs mentioned above ? It could be that the traditional methods of

N86-19931

CAN PLANTS GROW IN QUASI-VACUUM ?

M. André and Ch. Richaud

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The problem of the effect of neutral gas on growth of plants was the motivation of ancient experiments of Schloesing (1897)[1] who observed that nitrogen and argon were not consumed by plants and who concluded that they were probably useless. Since to date we have known that nitrogen can be used by legume plants, but 10 percent of nitrogen is sufficient to supply this process. The question remains to know what happens if, for the same partial pressure of $O_2$, the nitrogen is suppressed and so, the total pressure falls drastically ? In other words, knowing that only 5 % $O_2$ (50 mb) is sufficient to maintain plant respiration and that the pressure of $CO_2$ and water vapour represent around 25 mb in the normal atmosphere, is it possible to conceive of growing plants with only an absolute pressure of 75 mb i.e. a quasi-vacuum ? The predicted answer, following the theory of molecular diffusion of gas is positive but the physiological verification is necessary.

A first positive assay of growth without nitrogen in low pressure was made in the laboratory and mentioned in a space biology meeting (Guérin de Montgareuil et al.)[2], because this theoretical question could also concern space technology. The plant cultivation in space environment is not so far away as we imagined, taking into account the active research of CELSS project (Controlled Ecological Life Support System) in which growth of plants and algae is planned for food supply of long distance manned space mission (Moore et al.)[3]. For theoretical and practical reasons it seems useful to analyse experiments in which low pressures were imposed to plantlets

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## BLSS, A European Approach to CELSS

N86-19908

Å. Ingemar Skoog
Dornier System GmbH
Friedrichshafen, Federal Republic of Germany

rolled ecological life support systems ave for some years been subject to in- studies and experiments in the U.S. .S.S.R., and in Europe and Japan as recent years.

presently planned Space Station con- esee an early implementation of water n recovery in order to reduce resupply d volume. In view of expected increase n and crew size the spacecraft payload ns will require that the carbon, or ycling loop, the third and final part fe support system, be closed to further gistics cost. This will be practical dvanced life support systems can be de- n which metabolic waste products are ed and food is produced.

ier System has in recent years underta- fort to define requirements and con- to analyse the feasibility of a Biolo- e Support System (BLSS) for space ap- s. Analyses of the BLSS energy-mass re- ve been performed, and the possibili- nfluence it to achieve advantages for (compared with physico-chemical systems) determined. The major problem areas which need immediate attention have been defined, and a programme for the development of BLSS has been prosed.

A feasibility study of a closed life support system for plant and animal experiments in space has been initiated and results will be verified by bread-board testing of selected alternatives. The principle is to form a chain of ECO-groups consisting of food producers, consumers and decomposers, of which one (plants or animals) will contain the life science test species. Considered possibilities are combinations of aquarium concepts, algae reactors and vertebrate vivaria.

This paper discusses the BLSS feasibility analyses activities performed in Europe, the ongoing experimental/development work and future planning for European BLSS activities.

FOR EXTENDED DURATION MISSIONS in space the practical supply of basic life-supporting ingredients represents a formidable logistics problem. The weight at launch and the storage volume in weithlessness of water, oxygen and food in a conventional non-regenerable life support system are directly proportional to the crew size and the length of the space mission. In view of spacecraft payload limitations, the inescapable conclusion is that extended-duration manned space missions will be practical only if advanced life support systems can be developed in which metabolic waste products are regenerated and food is produced.

Only a Biological Life Support System (BLSS) *, which not only satisfies the space station environmental control function requirements, bus also closes the food cycle, can meet all the expected requirements. A BLSS must be a balanced ecological system, biotechnical in nature and consisting of some combination of human beings, animals, plants and microorganisms integrated with mechanical and physico-chemical hardware.

# CEA Scientific Inspiration

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- Bjorkman 1968, Stanford university, influence of low O2 seems to give better plant growth,
- CEA Visit to Stanford, Disappointing hardware (e.g. wood structure),
- Good CEA knowledge to handle radioactive products in airtight chamber.
- Proposal to use $^{14}C$ and $^{18}O_2$,
- 1968 : $C_2$3A proposal accepted

# 8 Twin Chambers

# Several shapes

# HPC Roots Zone

# Multiplexed MassSpectrometer

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# Control System

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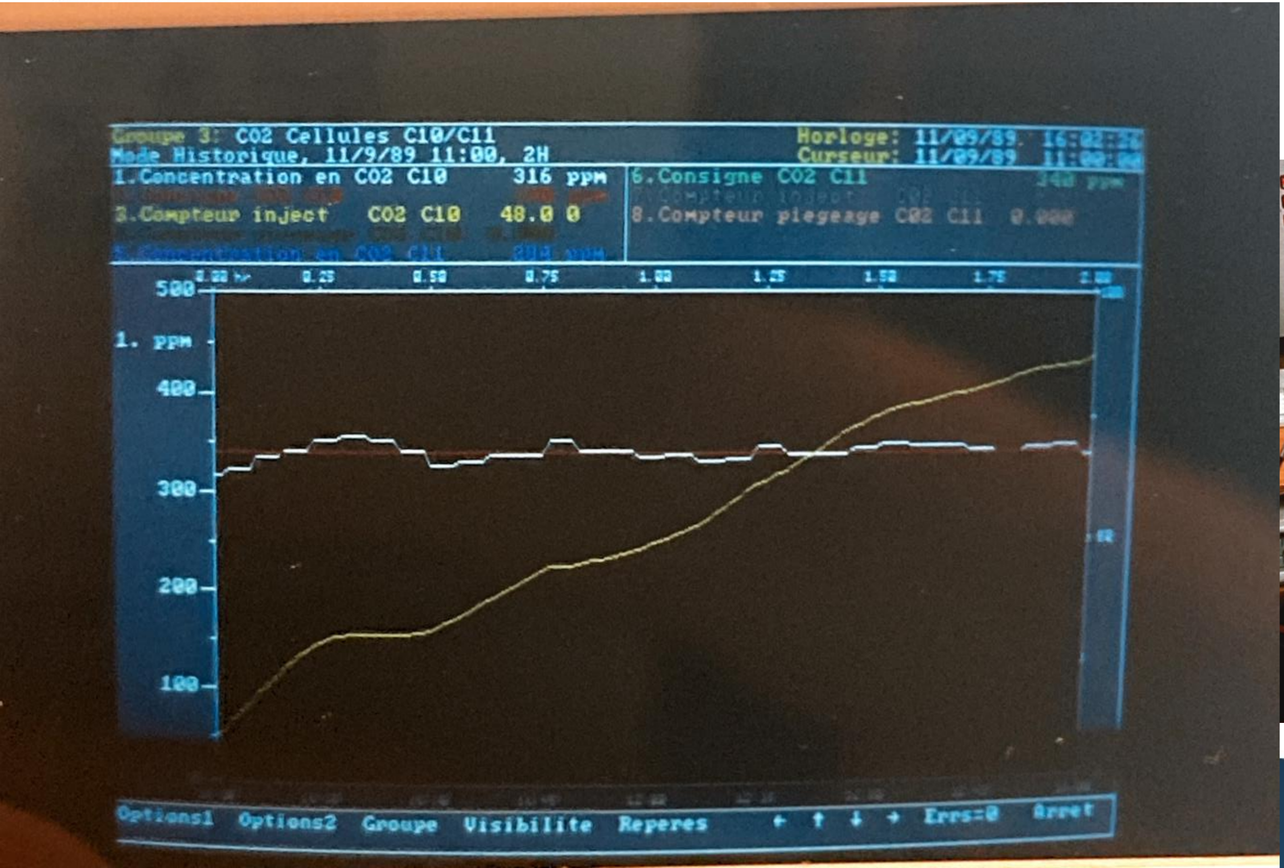


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- List of
- Mainly ... ligh CO2, ... ,..), but nc
- To our
- Seeds ... , B. Saugi

Classement des travaux réalisés
depuis le $C_2$3A (1969), le LACC, le LAP ....

**Les publications concernant plus particulièrement les études d'écosystèmes artificiels dans une perspective spatiale sont en caractères gras**

**(mise à jour Mai 1997)**

0[8]- André M., Guérin de Montgareuil P., Seimandi N., 1967. C.R. Acad. Sci. Paris, 265, 543

0[7]- Guérin de Montgareuil P., André M., Seimandi N., 1967. C.R. Acad. Sci. Paris, 265, 485

0[6]- André M., Gerster R., Legrand B., Montigaud J.-M., 1970. Ensemble de régulation de pressions partielles de gaz. Rapport DEG/SEIN n° 10585-R-85 Décembre. SEIN Cadarache 13108 Saint-Paul lez Durance cedex.

**05- Guérin de Montgareuil P., André M., Lespinat P. Mesure instantanée des besoins metaboliques des plantes : applications agronomiques et éventuellement spatiales. Proceedings of Colloquium on Space Biology related to the Post-Apollo program. Paris. 1971. ESRO ed. Paris.**

0[4]- André M., Nervi J.-C., Lespinat P.-A., 1972. Régulation par échantillonnage à partir d'un spectromètre de masse de cellules de culture en atmosphères artificielles. Automatique et Informatique Industrielle, n° 9, Octobre 1972, 27-31.

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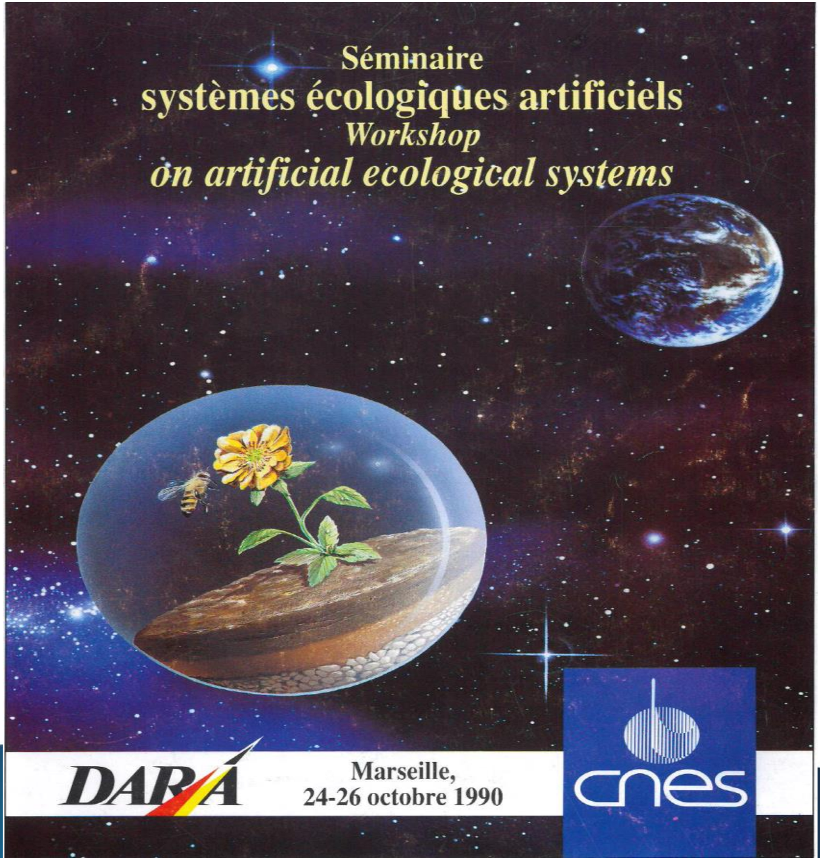
# $C_2$3A Team & Invite

# First CELSS European Workshop



# Matra Espace ~1986

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- MATRA Espace was contacted by CNES (Hervé Bouzouklian) for an experiment on board the Chinese rocket Longue Marche (launch in 1987),
- Claude Chipaux created contact between MATRA and CNRS Gif sur Yvette, leaded by Pr Marcelle Lefort-Tran,
- Pr Lefort tran was in contact with Pr Lester Packer in Berkeley who was a contractor of R.D. Mac Elroy,
- This CNRS-Berkeley-NASA link induced the AIRBUS-CEA connection,

# 1st Flight Experiment

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## ECOLOGICAL ALGAL SYSTEM IN MICROGRAVITY CONDITIONS – PRELIMINARY RESULTS

***G Dubertret, *M Lefort-Tran & **C Chipaux**

**Bioénergétique Cellulaire et Cytophysiologie, CNRS, Gif sur Yvette, France*
***Applications de la microgravité, MATRA, Vélizy-Villacoublay, France*

ABSTRACT/RESUME

In the aim of the program to analyse the biological and technical problems raised by food production and regeneration of atmosphere in microgravity, an experiment of algae culture has been launched from China by a Long March II.

By combination of heterotrophic growth of Euglena plastid mutant (oxygen uptake and $CO_2$ evolution) with the autotrophic growth of Nostoc (cyanobacteria, oxygen evolution and $CO_2$ uptake) a closed ecological algal system has been experimented.

Keywords : Algae, Cyanobacteria, Cultures, Closed system, Microgravity.

### 1. INTRODUCTION

Projects of space habitation for long duration flights have opened the research program usually named CELSS (Closed Ecological Life Support System). The aim of this program is to analyse the biological and technical problems raised by food production and regeneration of respirable atmosphere and waste products in microgravity conditions.

We describe here an experiment of algae culture in orbit (orbit inclination : 62.95°; apogee 406 Km, perigee 172 Km ; period 90.175 min.) flown from August 5th to August 10th 1987, from China (Setchouan) by a Long March II. The project was to sustain algal cell growth in microgravity conditions and in a closed atmosphere by combining the heterotrophic growth of a plastid mutant of Euglena (oxygen uptake, $CO_2$ evolution) with the photosynthetic growth of a filamentous cyanobacteria Nostoc (oxygen evolution, $CO_2$ uptake). If such cultures proved to be successful in control laboratory conditions, possible effects of microgravity such as the absence of convection had to be verified. Moreover, additional difficulties laid on technical conditions, i.e. the limited space and weight (1715 g) available and the 2 months duration of the preparatory phase before the flight, during which cells had to survive in resting conditions.

### 2. MATERIAL AND METHODS

The heterotrophic bleached mutant of Euglena gracilis was suspended in a Greenblatt and Schiff culture medium containing glutamate and malate as organic carbon source (Ref. 1). The photosynthetic filamentous cyanobacteria, axenic strain, Nostoc 7524 (Pasteur collection) were maintained in the mineral medium BG11 (Ref. 2). Cell cultures (6 samples for Euglena, 10 for Nostoc, 3 ml each) were separately packaged in 10 cm long, 0.5 cm in diameter dialysis bags which allow gas exchanges with the surrounding atmosphere. These bags were maintained in place by perforated plexiglass tubes held in the 350 ml (13 x 3.5 x 7.5 cm) experiment container made of aluminium AU4G and surface treated with alodyne (Fig. 1)

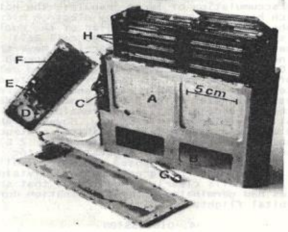


Fig. 1 - Artist view of the container opened after landing. Container (A), location of batteries (B); electronics (C); cover (D) equipped with the light bulb (E) and the ampule breaking system (F); broken ampule (G); 16 perforated plexiglass tubes (H), each containing one dialysis bag. All exposed surfaces were blackened by osmium tetroxyde.

*Proceedings of the 3rd European Symposium on Life Sciences Research in Space, Graz, Austria, 14–18 Sept. 1987 (ESA SP-271, Dec. 1987)*

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# 1987 Proposal to CNES

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1987

PROJET PRÉSENTÉ AU CNES POUR LE DÉVELOPPEMENT DE LA TECHNOLOGIE CONCERNANT

L'AMELIORATION DE L'EFFICACITE PHOTOSYNTHETIQUE ET DE LA BIOMASSE

POUR LA PRODUCTION DE CYANOBACTERIES CONSOMMABLES PAR L'HOMME


Principaux chercheurs :

Lester PACKER[1]

Marcelle LEFORT-TRAN[2]

Marcel ANDRE[3]

Guy DUBERTRET[2]

1 - Lawrence Berkeley Laboratory, University of California

2 - Laboratoire de Bioénergétique Membranaire et de Cytophysiologie, ER 308, C.N.R.S., Gif sur Yvette

3 - Laboratoire de Radioagronomie, Centre d'Etudes Nucléaires de Cadarache, St Paul-lez-Durance.

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- In 1987, C … n HERMES
  developm…
- AIRBUS (C … rgeay
  during an… Belgium,
- A new pro… Microalgae
  to a close…

29.10.87 :

Visite Matra : CHIPAUX

question posée :

écosystème qui fournit l'$O_2$

le cosmonaute fournit le $CO_2$

et recycle.

système à 2 composants :

NOSTOC : fournit $O_2$

Euglène : respire et fournit $CO_2$

(En fait, ce système s'appauvrit car la nourriture euglène est limitante.

# MELiSSA start

MATRA

Copies: D.K.
J.J.

J.F. REDOR
EUROPEAN SPACE AGENCY
ESTEC - YC
Postbus 299
2200 AG - NOORDWIJK
PAYS BAS

TSVH/L035/CC/DK/SA

Vélizy,
March 7th, 1988.

Dear Sir,

Following our discussion in Noordwijk during last February I am pleased to submit you here-enclosed the description of a closed ecosystem which has been established with the following concerns :

- It is aimed to stand as simple as possible, taking account of the presence of a "Consumer" (Animal).
- It is expected to be simple enough to make possible a sound mathematical modelization of its functionning.
- It is foreseen as able to be tested and operated in space, under low or microgravity conditions.
  This justifies the choice of micro-organisms as being probably the "bio-actors" most likely to withstand cosmic environment safely as well as presenting high biomass production efficiency and able to operate continuously.

At the moment, some effort has still to be paid in order to give this project its final shape before starting a phase A/B study. In that respect we would be grateful to get ESTEC's comments in return. The effort would consist in carrying along the bibliographic query and analysis and working out the dimensionning of bio-reactions parameters.

A first estimate of the contribution that we would ask ESTEC to bring in this preliminary study is 35 kau, for a 6 months duration, with the following breakdown :

| | | |
|---|---|---|
| C.N.R.S GIF (Photosynthetic unit) | - | 15 kau |
| C.E.N (Nitrification unit) | - | 15 kau |
| MATRA (Coordination and Paperwork) | - | 5 kau |

This proposal is submitted by :

M. MERGEAY of C.E.N MOL (B)

G. DUBERTRET, M. LEFORT-TRAN, A. TREMOLIERES of C.N.R.S GIF (F)

W. VERSTRAETE - RIJKSUNIVERSITY GENT (B)

C. CHIPAUX - MATRA (F)

With cooperation of :

L. PACKER - BERKELEY University (USA)

R. MAC ELROY - NASA Ames Center (USA)

We remain at your disposal for any discussion that you would wish.

Sincerely yours,

C. CHIPAUX

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# Conclusion

- There is (still) a large numbers of documents AND actors to illustrate the early days,
- If you have more info or comments please send them to me,
- As for Russia and Japan, European CELSS activities started around Nuclear centres (CEA and SCK) but not only,
- As for USA, its involved from the beginning a large scientific and multidisciplinary community,
- Fortunately enough, the European adventure still continue.

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# THANK YOU.

Christophe Lasseur
Christophe.lasseur@esa.int

www.melissafoundation.org

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