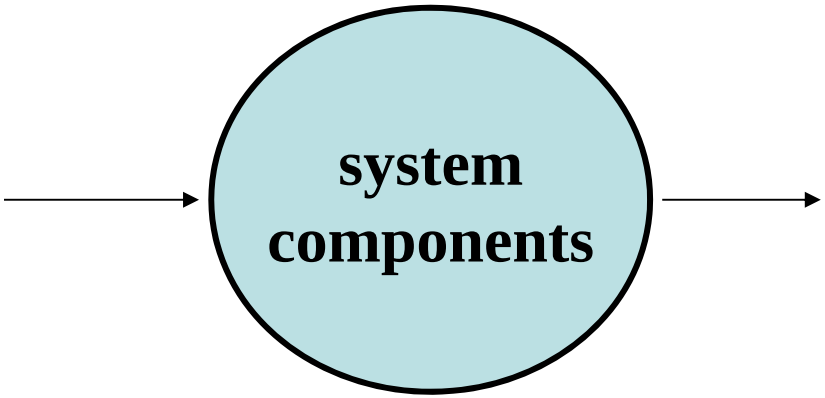
MELiSSA:The European project of Closed Life Support System

EMC 13, October 26th

IPSA, Ivry sur seine

Knowledge Transfer

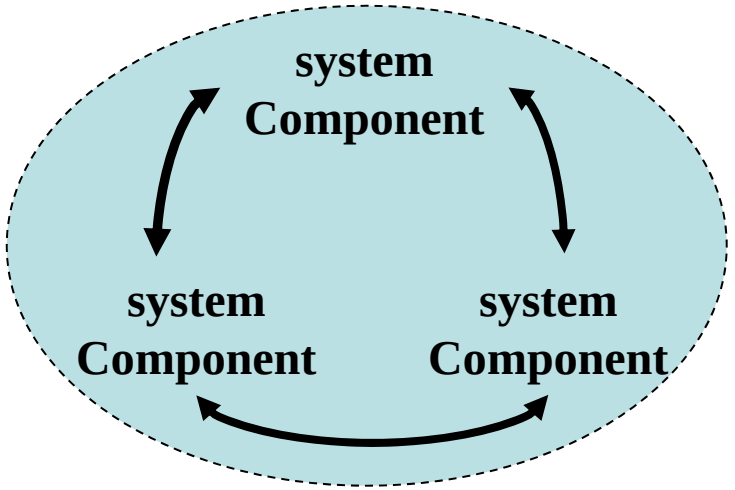
«Juvenile» system



Unlimited Resources

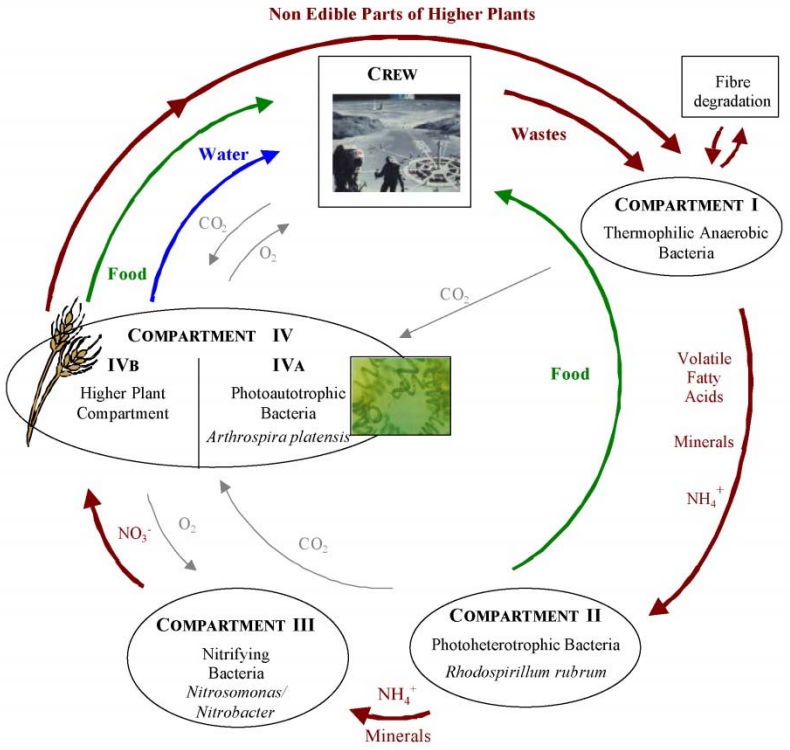
Unlimited Waste

«Mature» system



- Low consumption of resources
- Quasi-cyclical flows of materials

The MELiSSA Concept



Who ?

- Around 30 European organisations (from CDN, CH, B, D, DK, F, E, I, IRL,N, NL) participate :
  - Universities,
  - Public research centres,
  - SMEs,
  - Industrial World leaders,
  - Space companies,

- 11 of them have signed a M.O.U.,
- Around 70 persons are involved,
- ~ 50 % is academic manpower,
- On request of the partners, **ESA is in charge of the coordination,.**

The Scientific Challenges

- 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,
- …..

The Technological Challenges

- Robust modelling of all sub-systems,
- Modelling and control of A Closed loop system,
- Control of microbial consortium (axenicity),
- Detection (and modelling) of changes of nature of the sub-processes,
- To stay abreast of technological progress,
- Effects of Space Environment (reduced gravity, radiation,.)
- ….

The Management Challenges

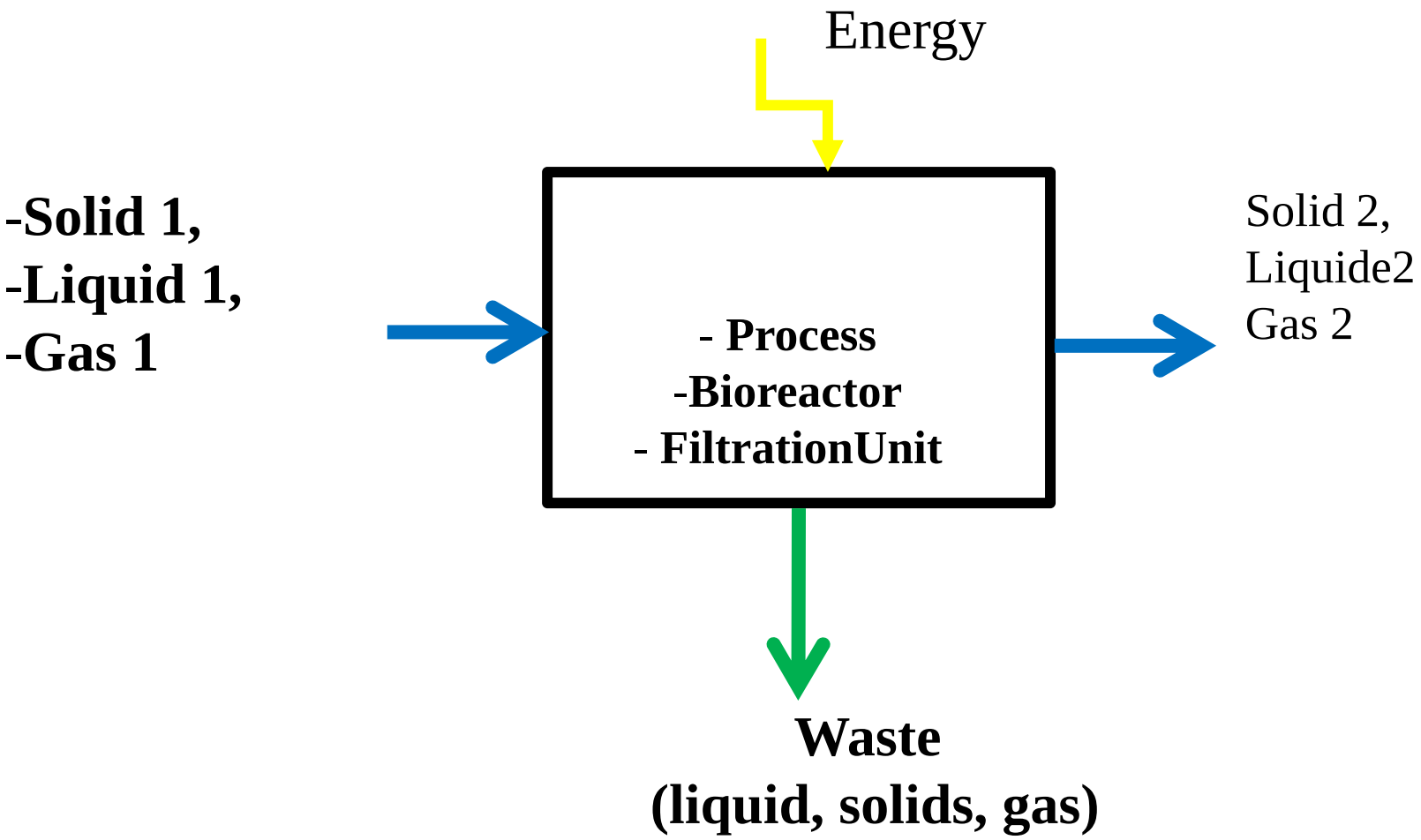
- To Convince the investors for the 40 years (or more) of the project development,
- To identify and convince CustomerS,
- To manage a very large, multicultural, and multidisciplinary group,
- To structure the project and to allow an historical and comprehensive control of all the database
  - Raw data, models, reports, software, manpower, budget,….

Organisation

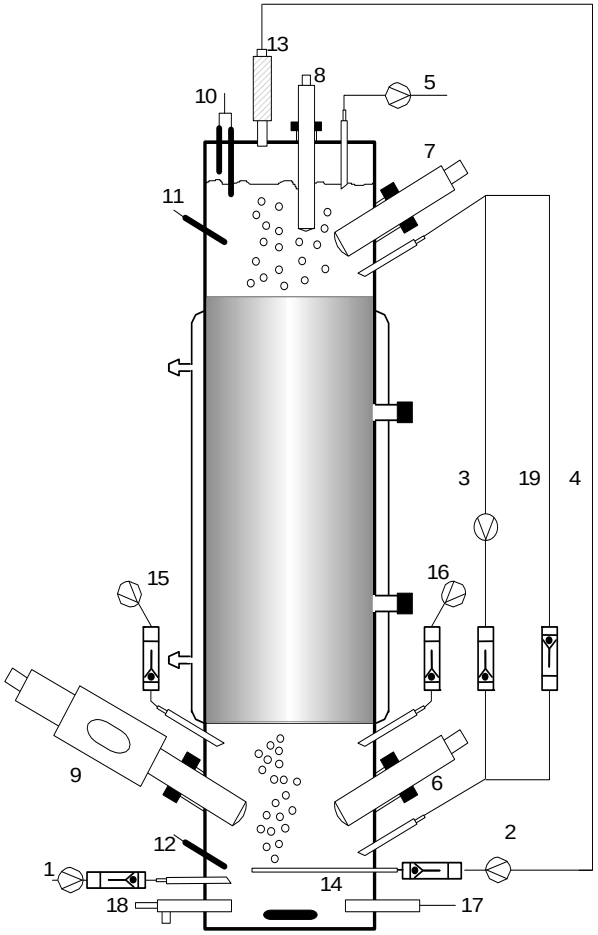
- The project organised in 5 parts (e.g. phases):
  - 1) Basic R&D
  - 2) Preliminary Flight Experiment
  - 3) Ground and Space demonstration
  - 4) Technology Transfer
  - 5) Education & Communication

Basic R&D

The approach Inputs / Outputs



MELiSSA : Compartment III (Nitrogen transformation)



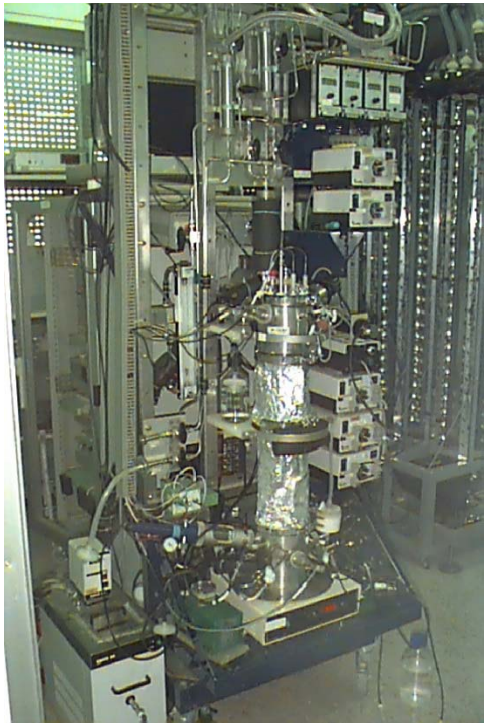
NH_4^+ ➡ **COMPARTMENT III** ➡ NO_3^-

Nitrobacter winogradskyi

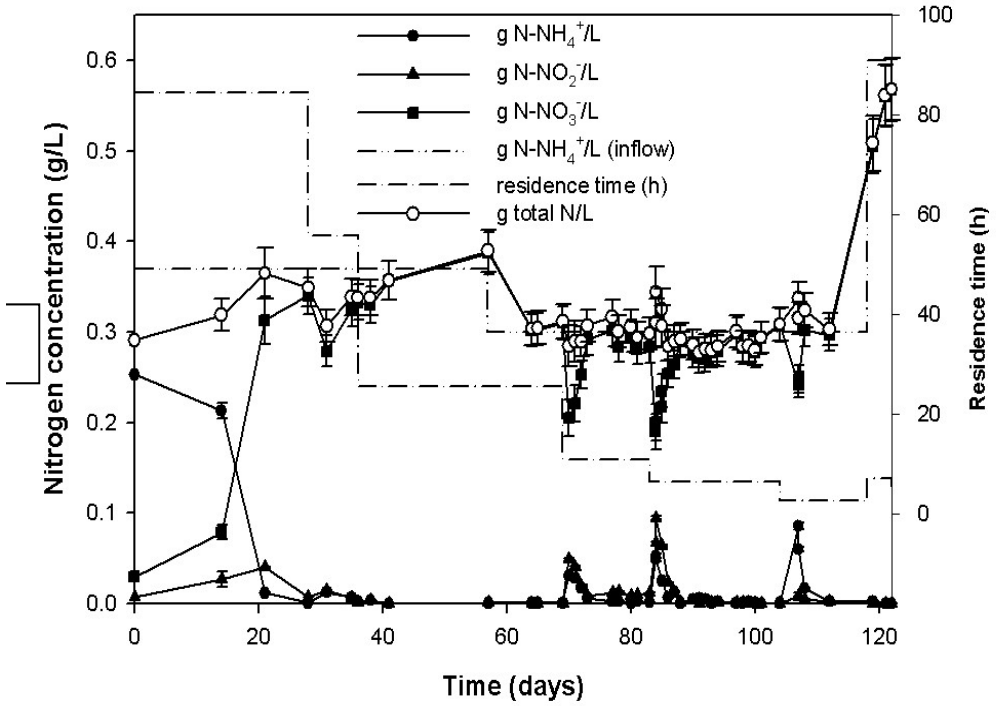
$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$

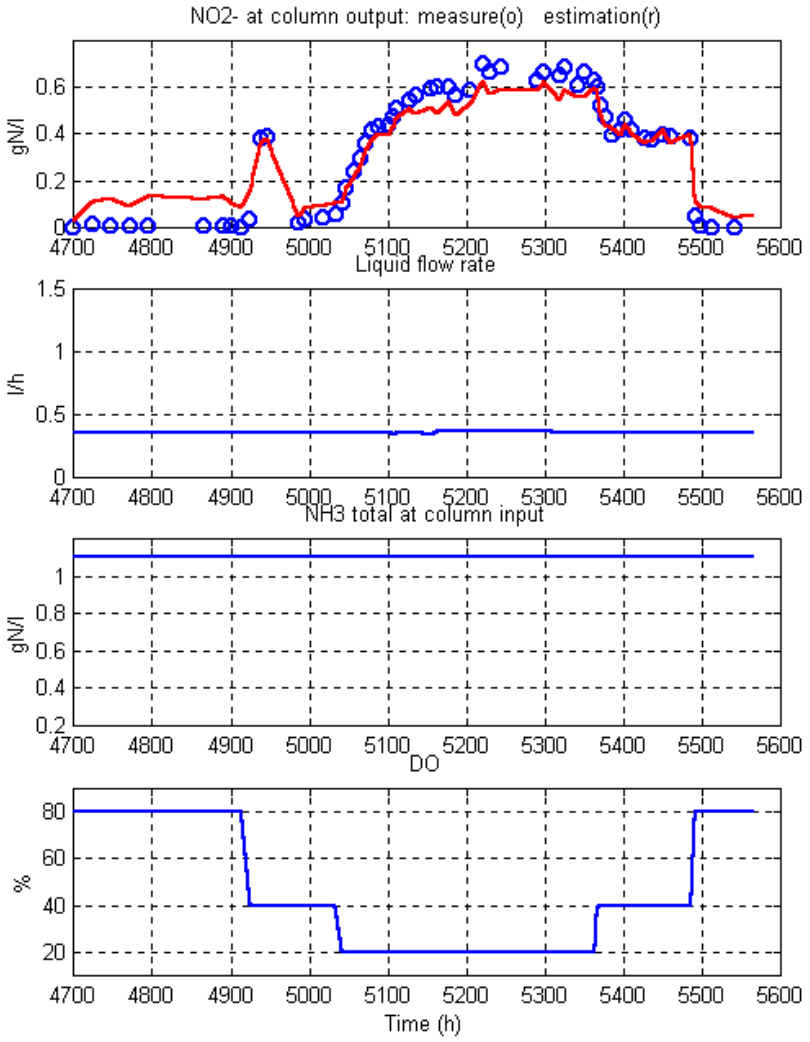
Nitrosomonas europaea

- ⇨ Packed-bed reactors
  Immobilized cells
- ⇨ Pilot scale reactors
- ⇨ Several reactors
- ⇨ Biofilm control



Characterisation



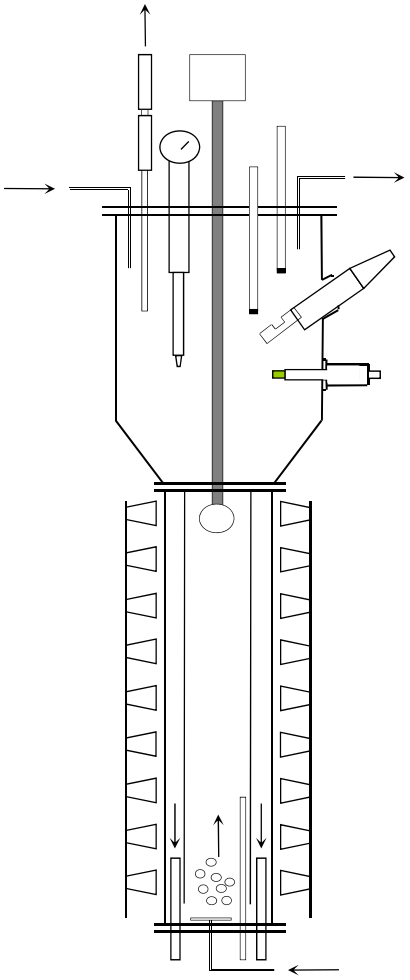


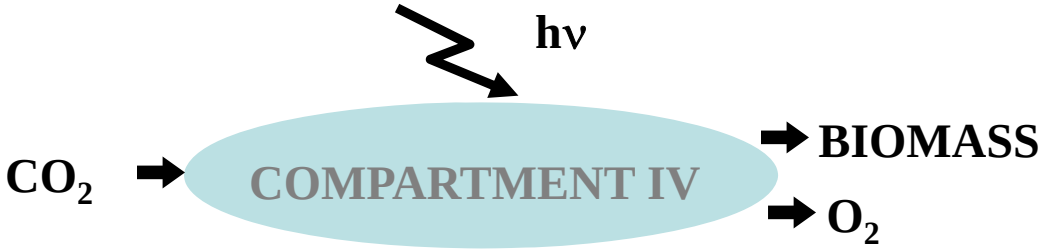
Variation of the Dissolved Oxygen

The Producer

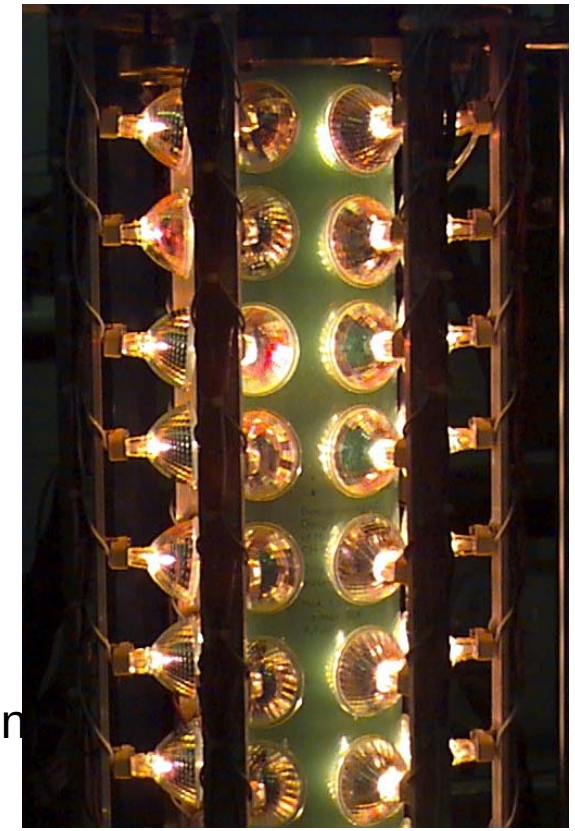
- Food, oxygen and water productions are organised via two processes:
  - An Algae compartment (IV a)
  - An Higher plant compartment (IV b)

MELiSSA : Compartment IV (Food/oxygen producer)

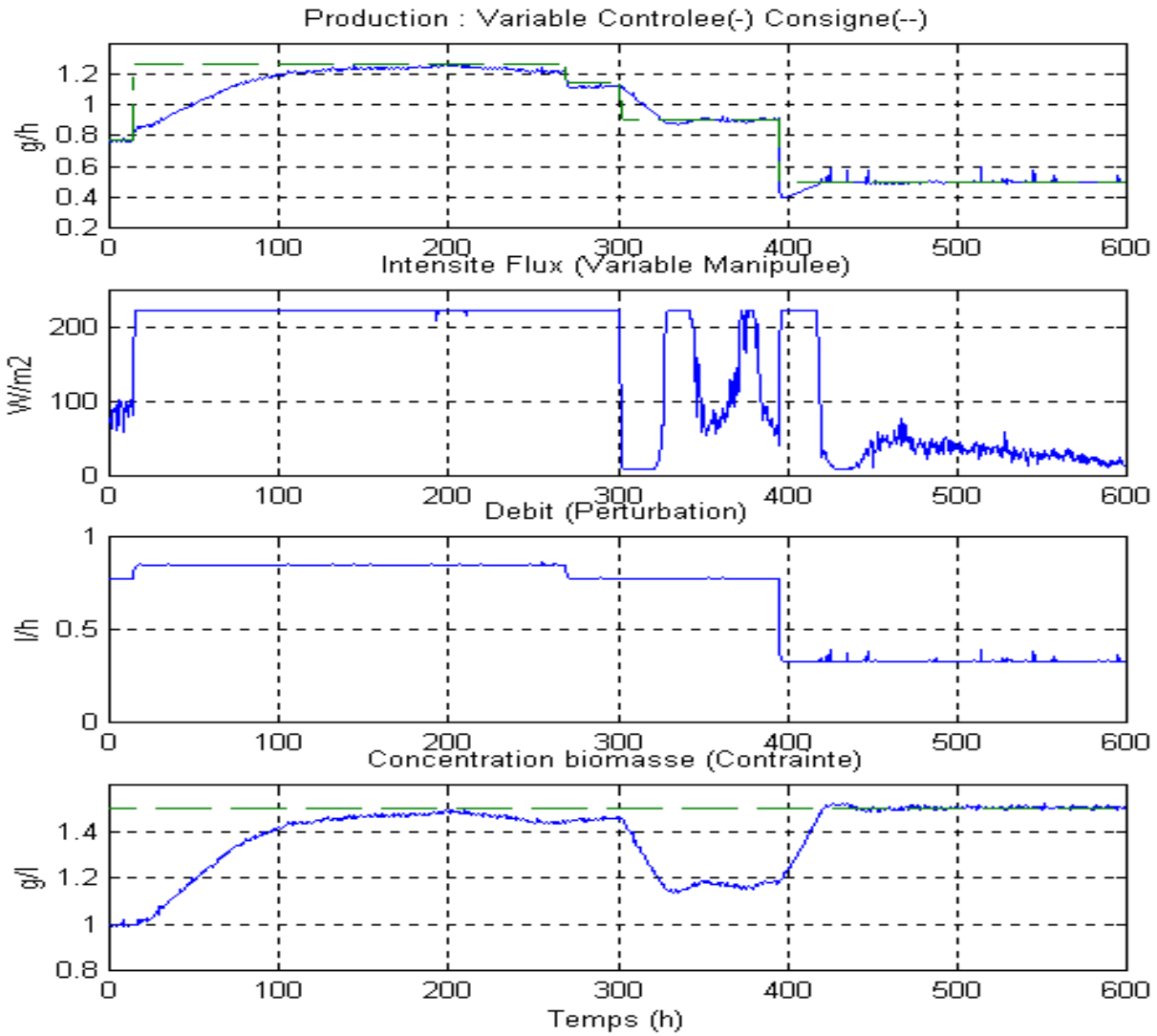




- Basic studies: strain, medium, etc.
- Complete math. modeling
- Design and installation of pilot reactor
- Continuous operation of the pilot reactor. Control.
- Scale-up
- Hydrodynamic characterization
  Opeartion of the pilot reactor

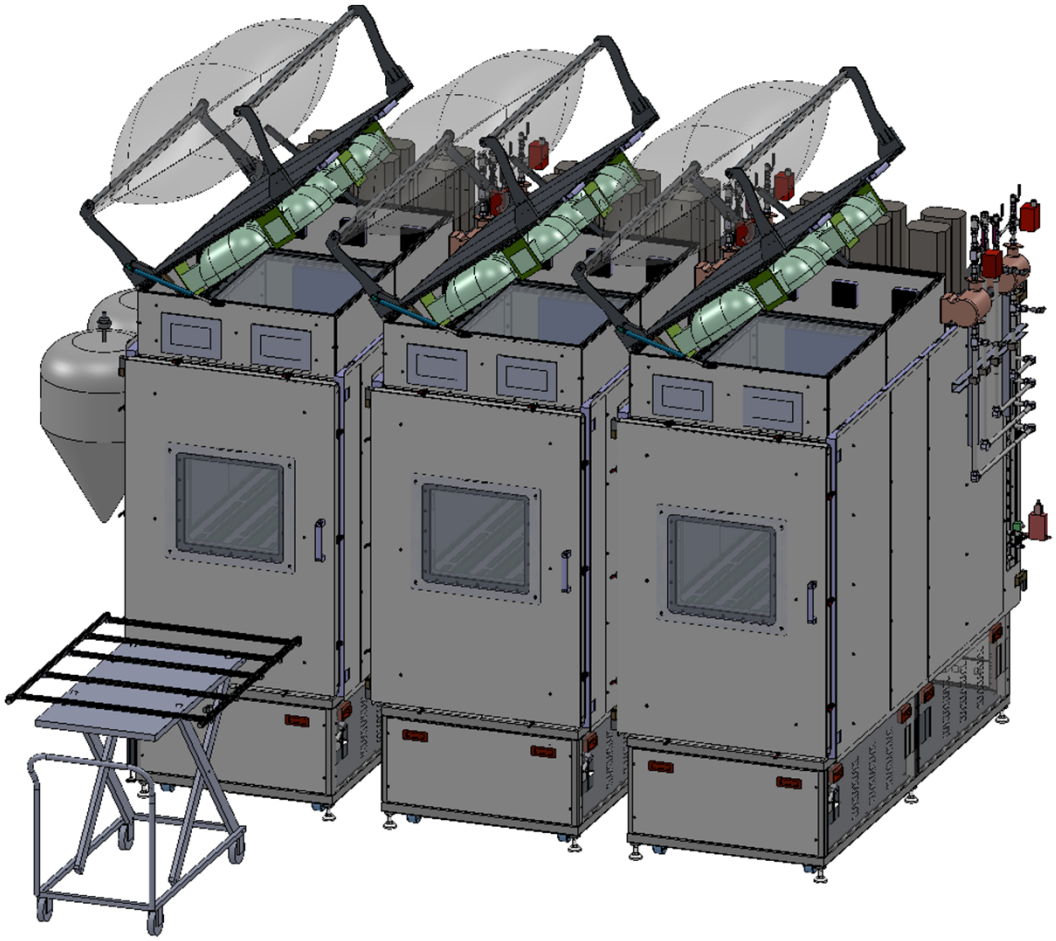


MELiSSA : Compartment IVa

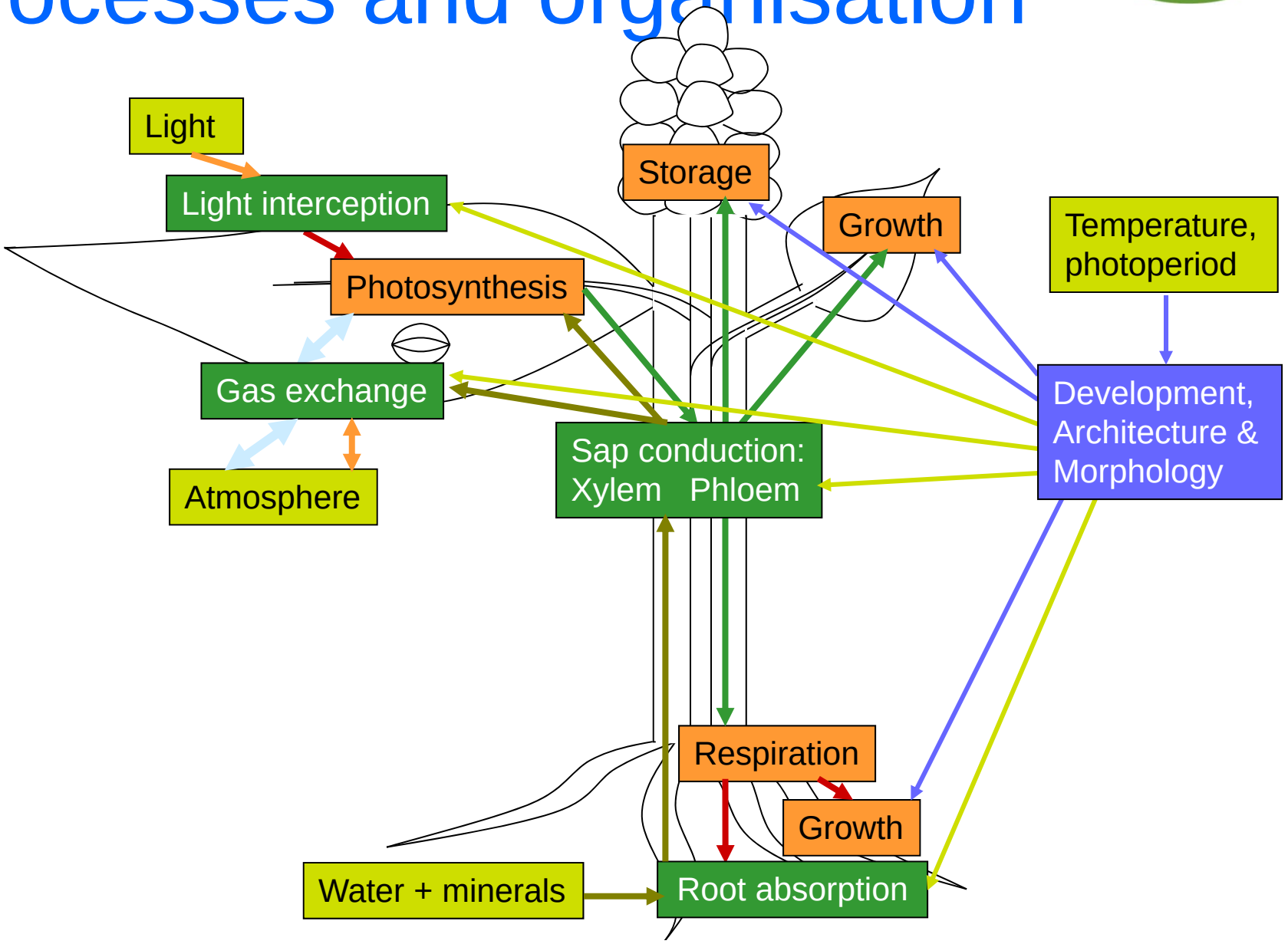


Plant Characterisation Unit

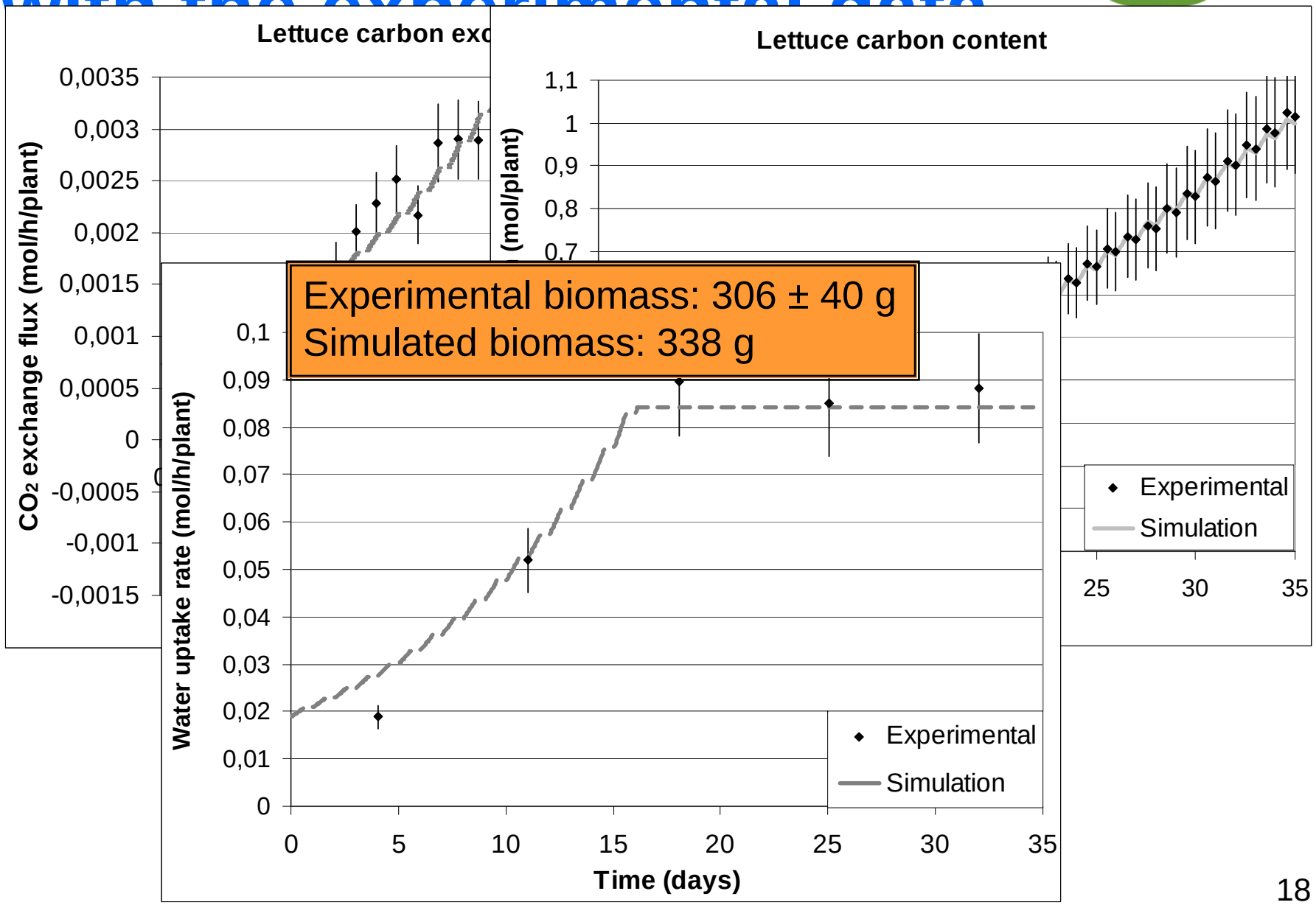
- Objectives:
  - Characte ent uptake, water up itions including
  - Characte utritional quality) u ncluding root micr
  - Develop nt growth
  - Develop tion and control o



Modelling: Main plant processes and organisation



Modelling: Comparison with the experimental data

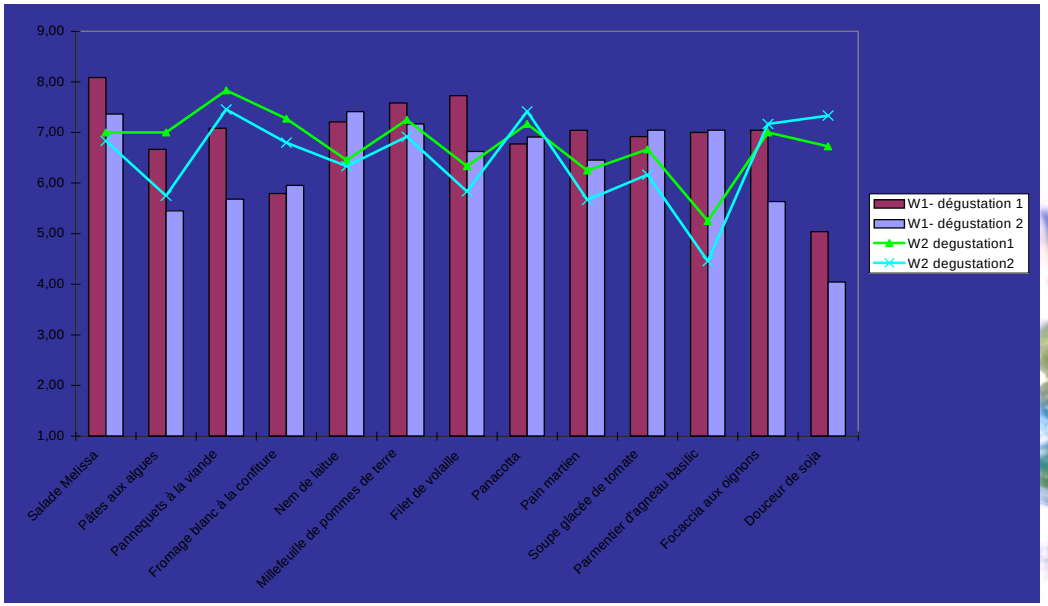


Food Preparation

- Definition of the food chain,
- Preliminary identification of critical issues,
- Preliminary identification of technologies for raw biomass transformation,
- Preliminary elaboration of recipes,
- Participation to Bed Rest,
- Creation of a food data base

Participation in Bedrest

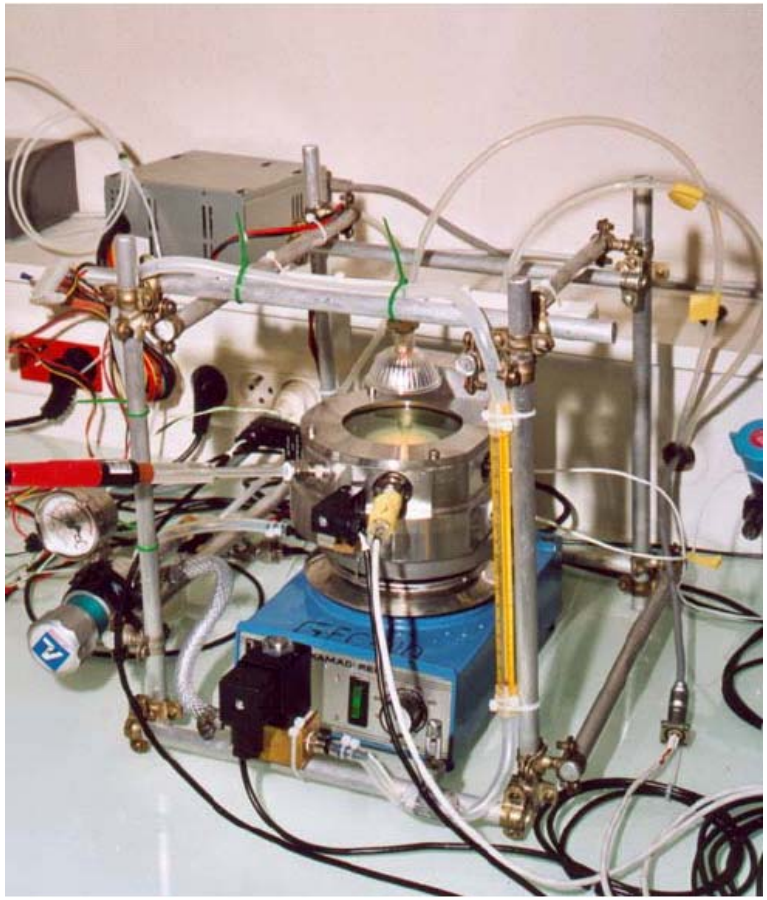
- ✓24 subjects (women).
- ✓3 groups: Controls – ***Exercise*** – ***Nutrition.***
- ✓Duration: 106 days for each successive period



Preliminary Space Experiments

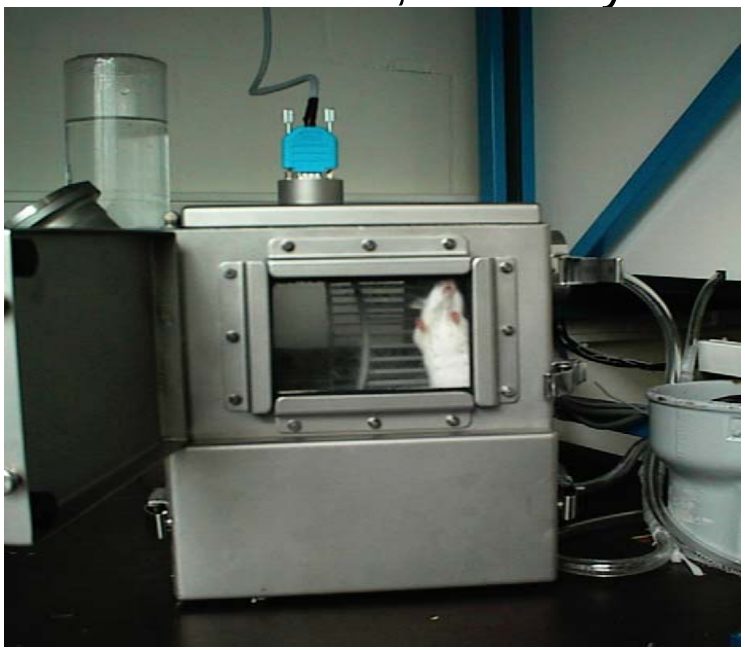
State of the Art

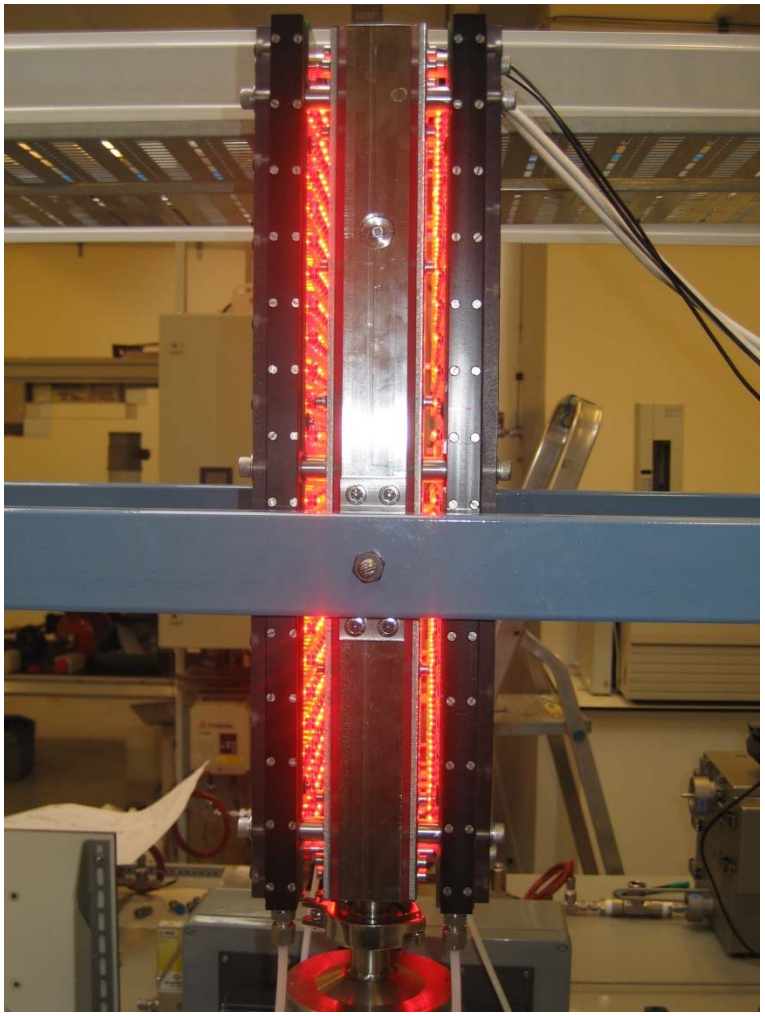
- MESSAGE 1: flown in october 2002
- MESSAGE 2: flown in october 2003
- BASE: flown in September 2006 and October 2009



State of the Art

- BIORAT (1997-today):
  - Laboratory demonstration was completed early 2000
  - Accommodation study for integration within ISS was completed late 2001
  - Prototype development started in 2004, currently under tests





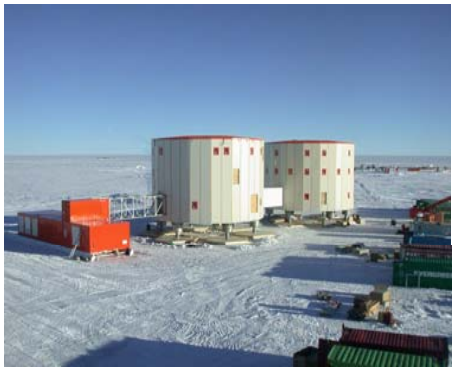
Schedule of future ISS Flight Experiments

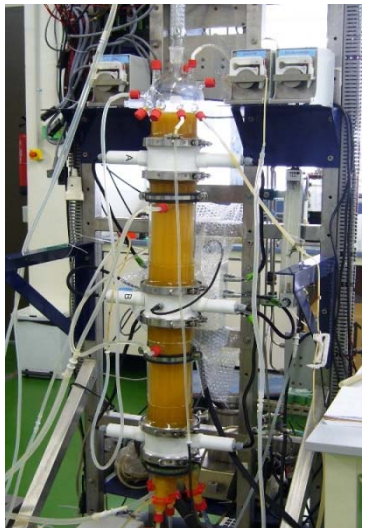
- **Artemiss** (expected flight in 2014): Photobioreactor
- **Biorat 1** (expected flight in 2017):Coupling Photobioreactor compartment with a consumer compartment
- **Biorat 2** (expected flight in 2020), Biorat 1+coupling of the nitrifying compartment

Integration for Ground Demonstration

ESA strategy

- **3 and potentially 4 facilities:**
  - In progress:
    - ESA:
      - MELISSA Pilot Plant (Barcelona)
    - Non-ESA:
      - Concordia Station (South pole)
      - BIOS (Russia)

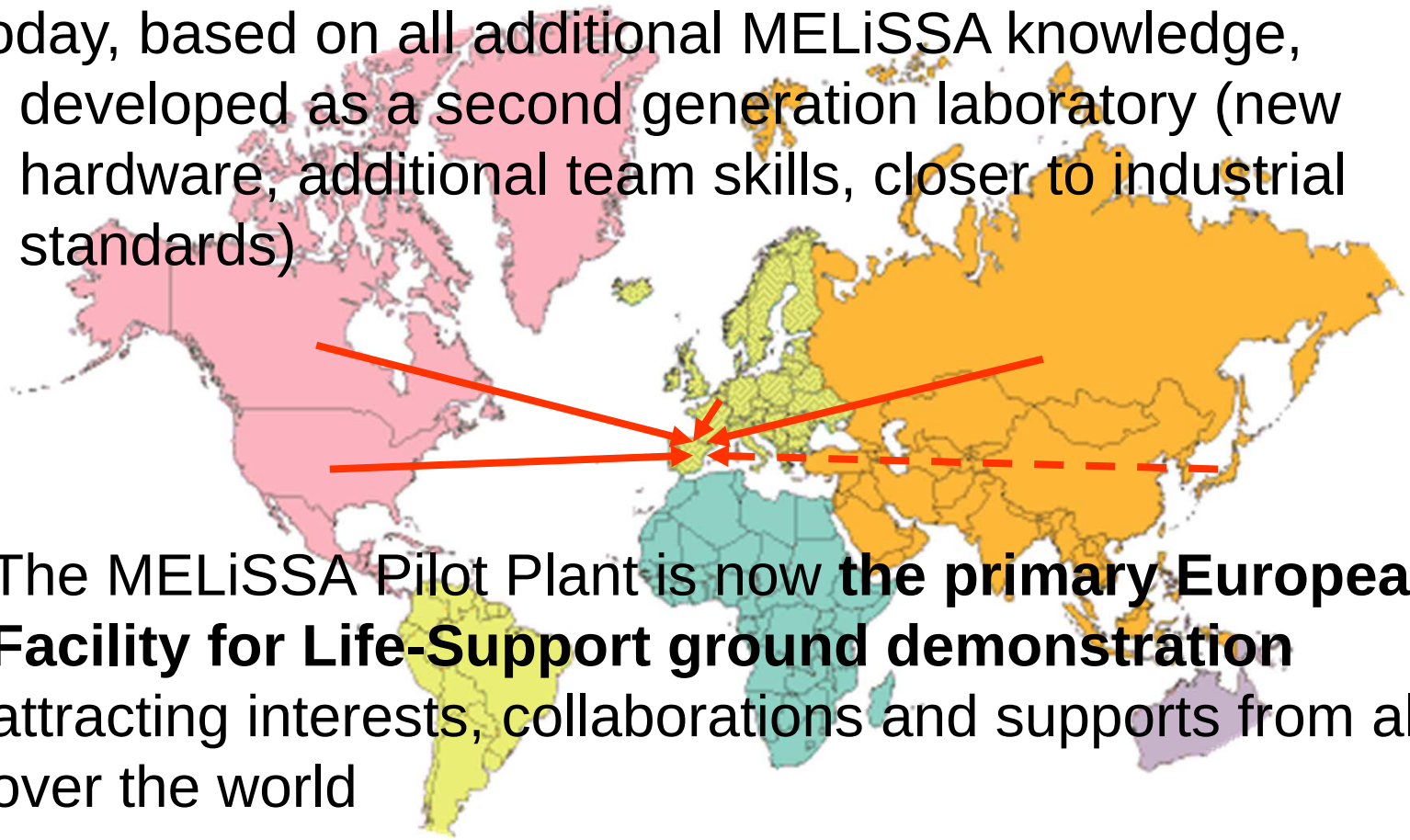




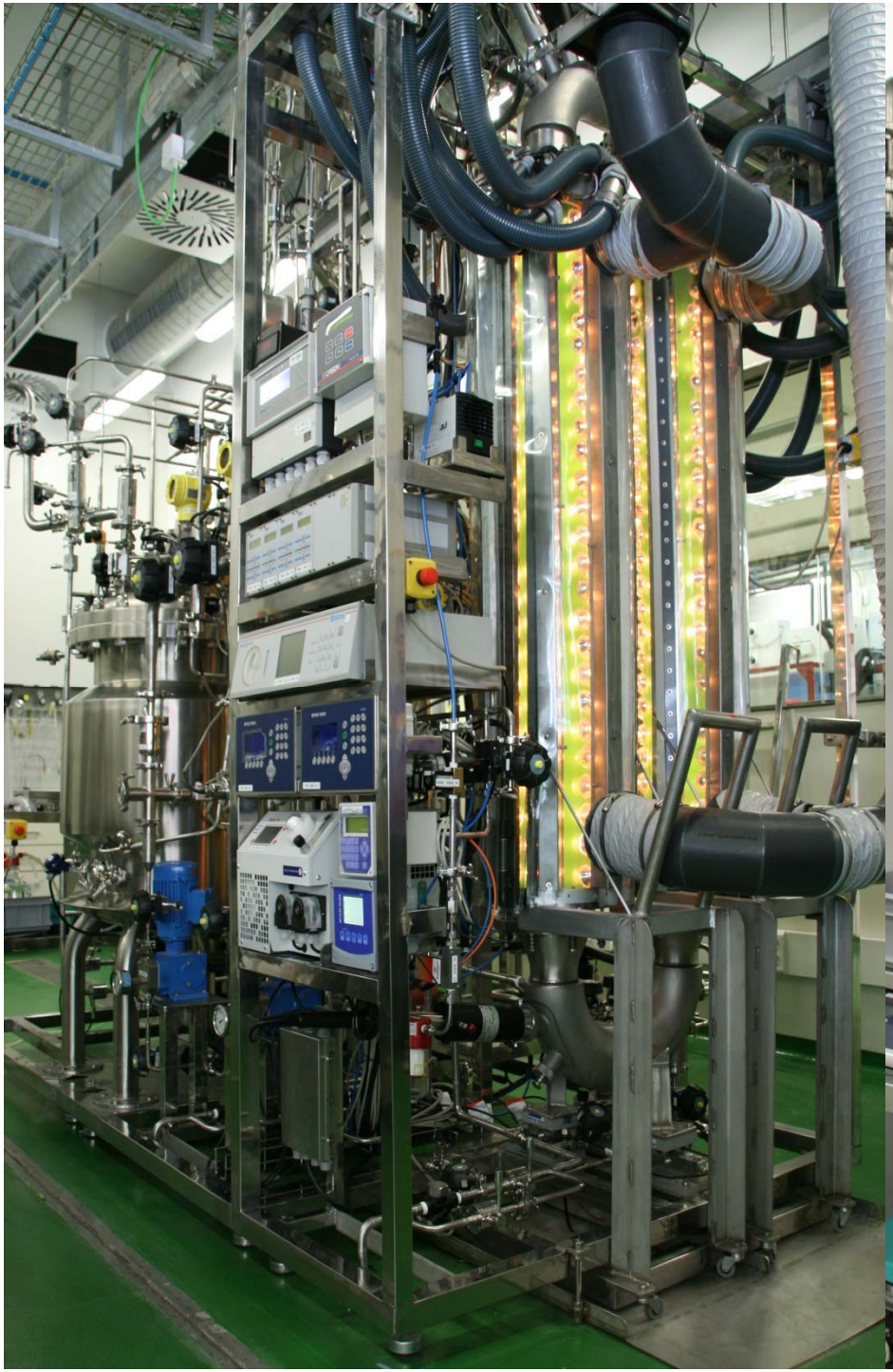
  - At feasibility level
    - a new European integrated facility (In Spain ?)

MELiSSA PILOT PLANT

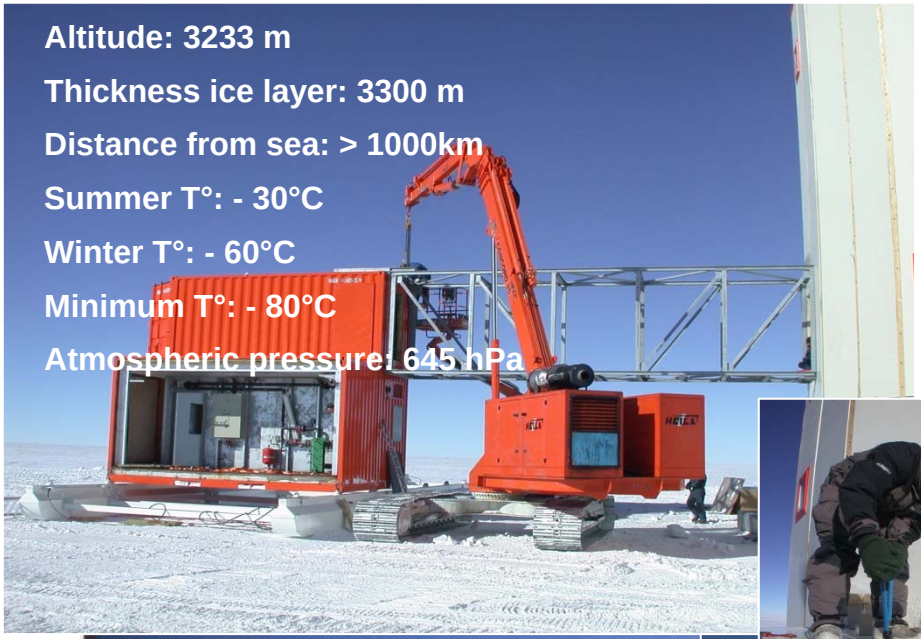
Today, based on all additional MELiSSA knowledge, developed as a second generation laboratory (new hardware, additional team skills, closer to industrial standards)



The MELiSSA Pilot Plant is now **the primary European Facility for Life-Support ground demonstration** attracting interests, collaborations and supports from all over the world



Concordia Station

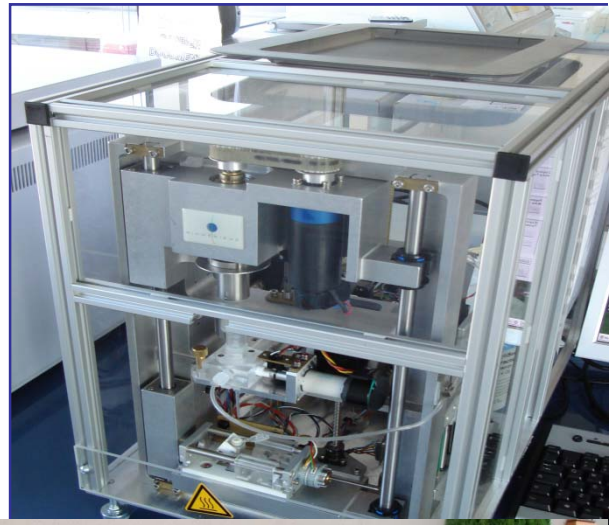


Technology Transfer

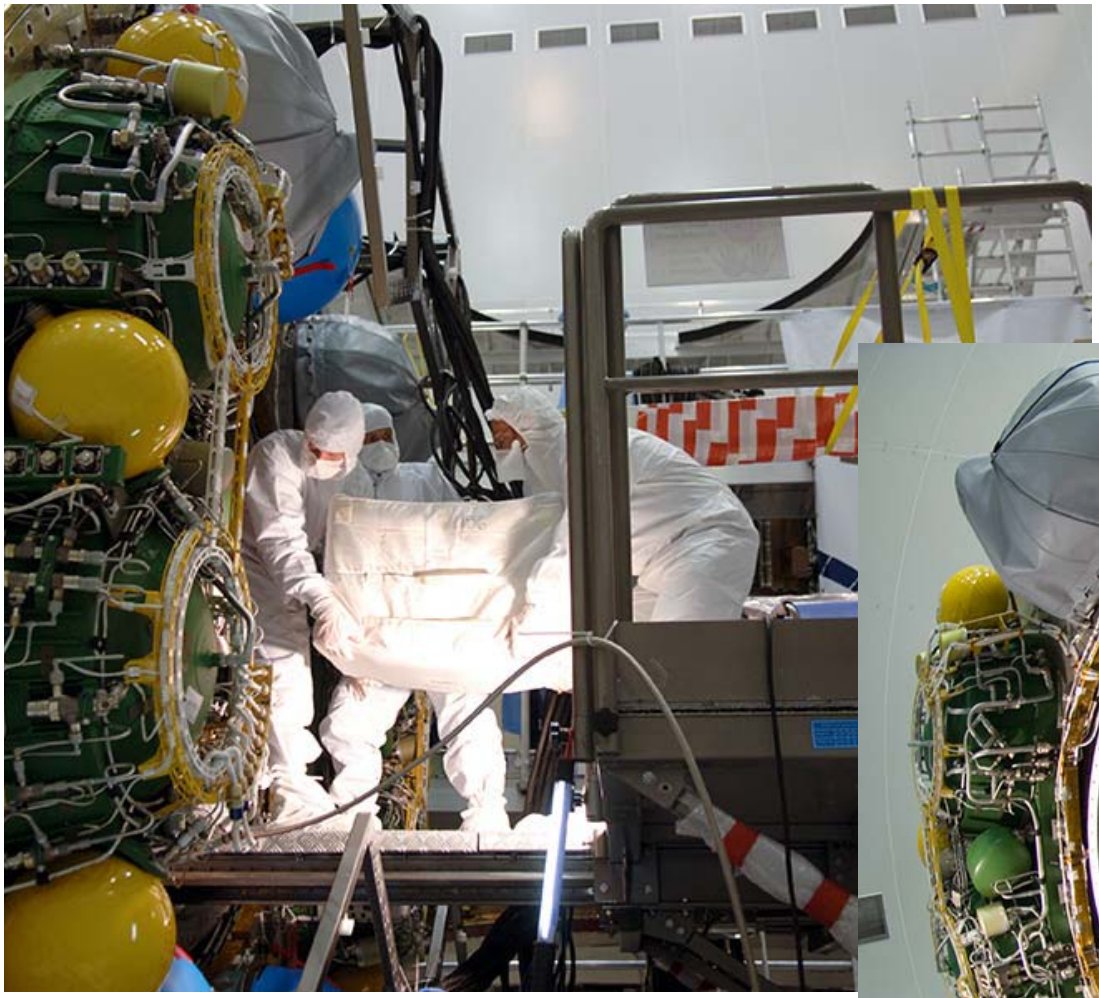
- Within ESA project (ATV, MIDASS)
- Terrestrial Application:
  - Two Spin-off companies:
    - IP Star,
    - EZ Col,

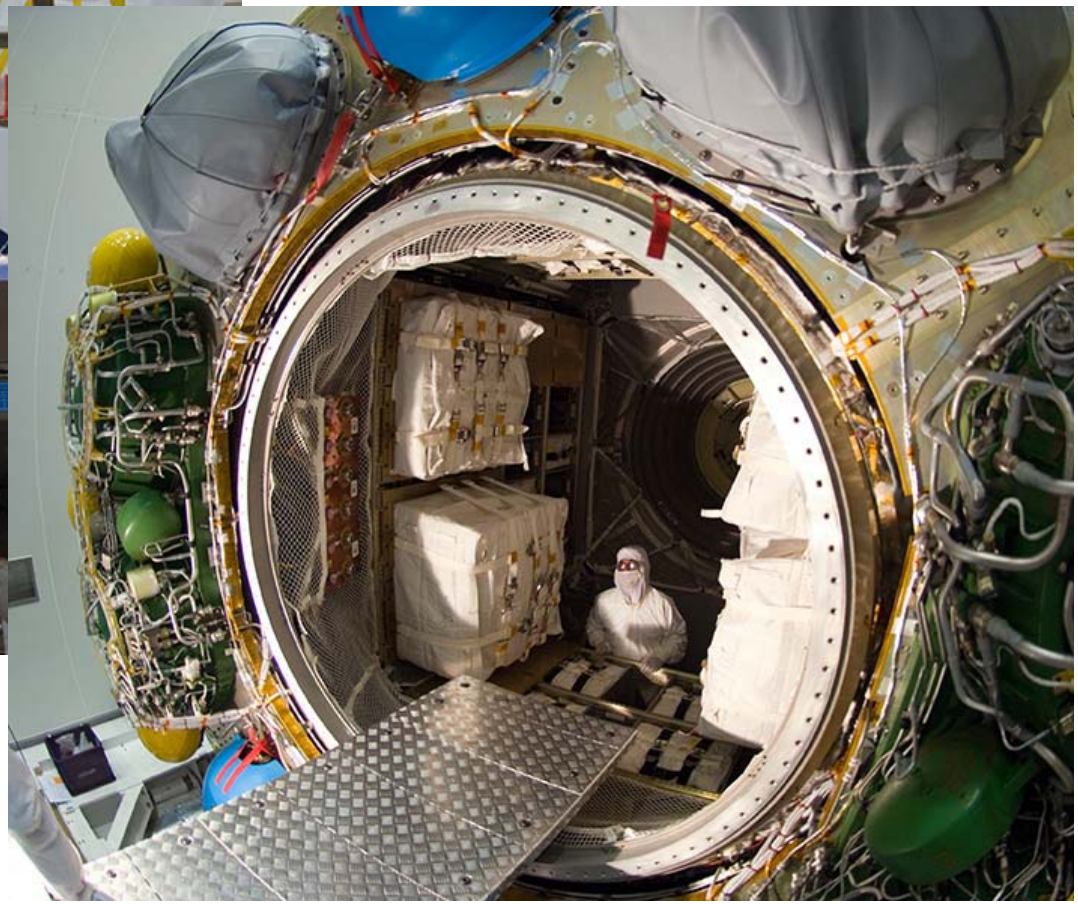
Microbial Safety (MiDASS)

- Fast Microbial Identification and quantification <3 hours
- Pan fungi, pan bacteria,
- Fully automated,
- Unique technology in the world,
- Large terrestrial market : from hospital to pharmaceutical industry
- Major Industrial investment
- Spanish industry is performing its Space adaptation (NTE/SENER)



ATV : The European cargo

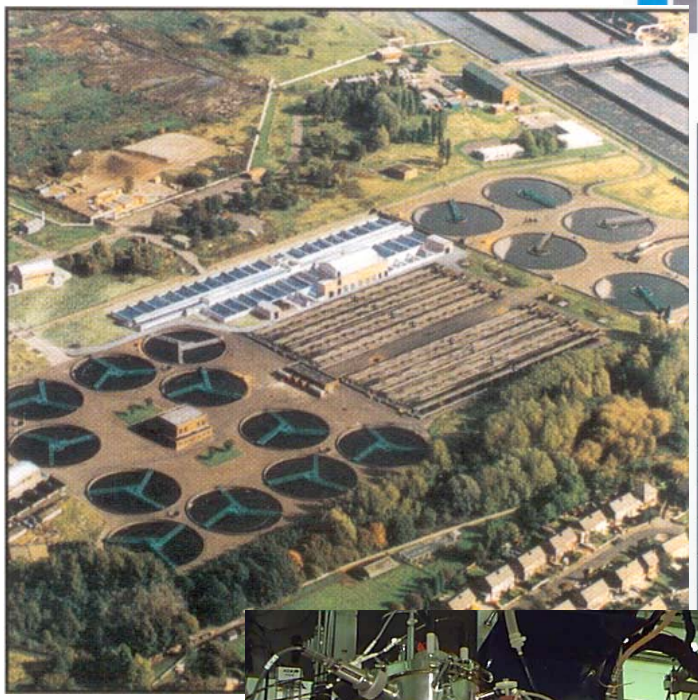


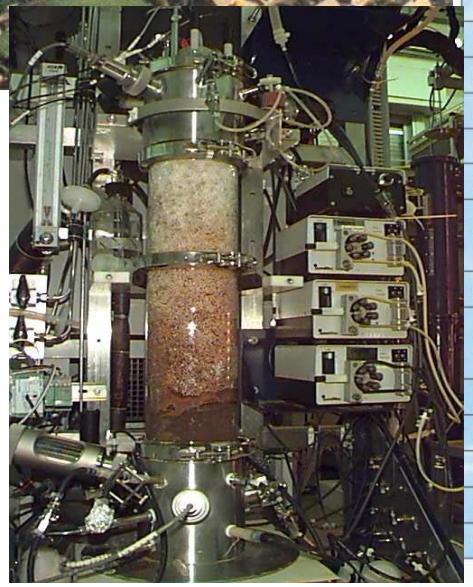


Quelques référenc

BIOSTYR

EAUX USÉES

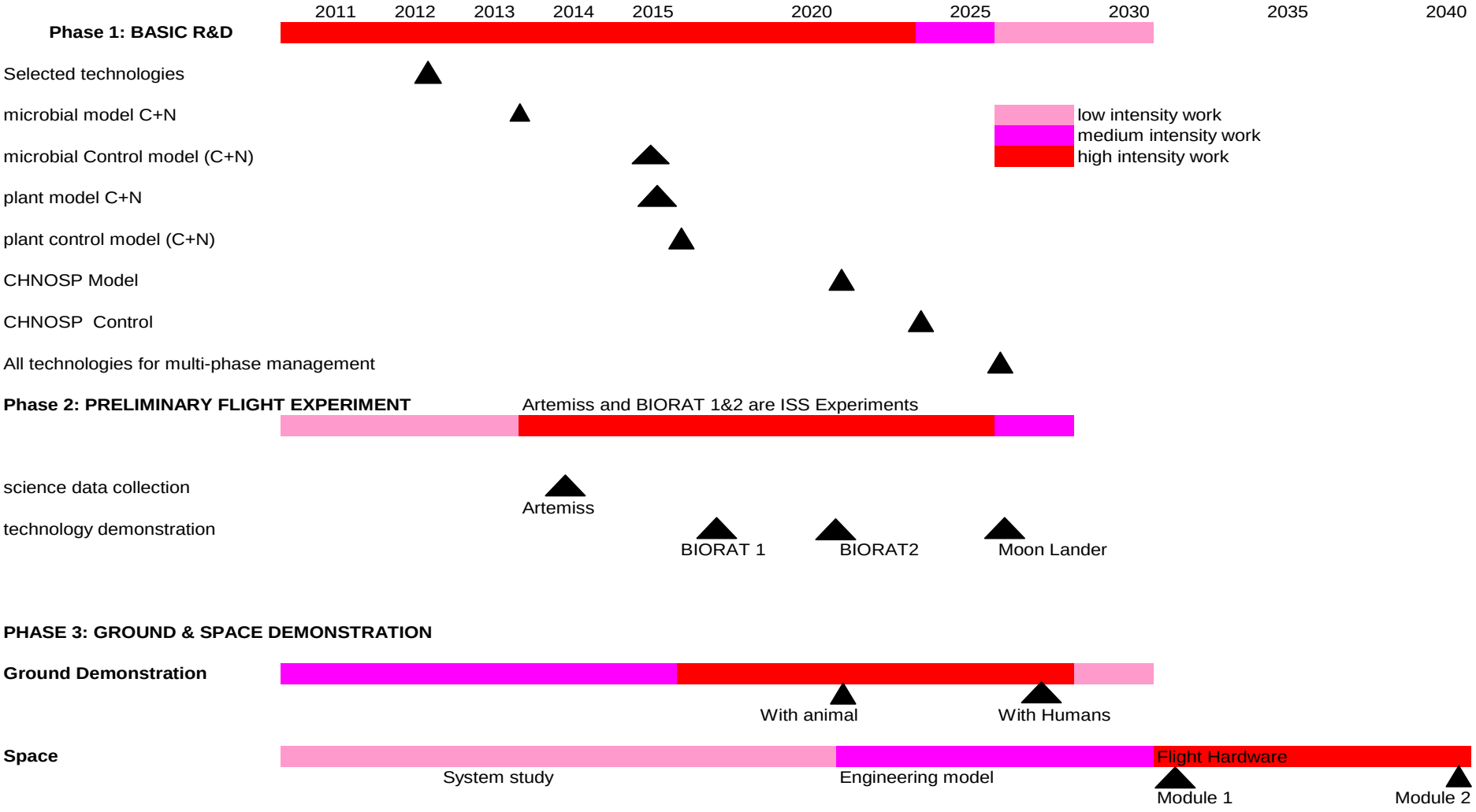




SITE	PAYS			
ST THIBAULT DES VIGNES LAGNY T4	FRANC			
PIAN SCAIROLO	SUISS			
DAVYHULME - MANCHESTER	GRANDE-BRE			
COLOMBES - PARIS	FRANC			
FRIELAS	PORTUGAL	1998	97 200	Elimination de la pollution carbonée
COLOMBIER	SUISSE	1998	18 000	Elimination de la pollution carbonée
ALTENRHEIN	SUISSE	1998	13 500	Nitrification-Dénitrification
ARACHES	FRANCE	1998	2 700	Nitrification
HERFORD	ALLEMAGNE	1997	33 000	Nitrification-Dénitrification
NEUCHATEL	SUISSE	1997	12 000	Elimination de la pollution carbonée
ALANYA	TURQUIE	1996	28 000	Nitrification
RAMBOUILLET	FRANCE	1996	10 800	Nitrification-Dénitrification
ROME SUD	ITALIE	1995	190 000	Nitrification
LYON ST FONS	FRANCE	1995	85 000	Nitrification
DAMMARIE LES LYS - MELUN	FRANCE	1995	24 000	Nitrification-Dénitrification
BLAGNAC	FRANCE	1995	7 000	Nitrification-Dénitrification
MARIAGER	DANEMARK	1995	2 800	Nitrification-Dénitrification + Post Dénitrification
ASSENS	DANEMARK	1995	2 000	
FREDERIKSHAVN	DANEMARK	1994	10 100	
HOBRO	DANEMARK	1994	9 100	
EVREUX	FRANCE	1993	20 000	
CERGY	FRANCE	1992	40 000	
NYBORG	DANEMARK	1992	13 000	
ST JEAN D'ILLAC	FRANCE	1990	2 100	

Water Recycling for Airbus

Roadmap


2011
2012
2013
2014
2015
2020
2025
2030
2035
2040
Phase 1: BASIC R&D
Selected technologies
microbial model C+N
microbial Control model (C+N)
plant model C+N
plant control model (C+N)
CHNOSP Model
CHNOSP Control
All technologies for multi-phase management
low intensity work
medium intensity work
high intensity work
Phase 2: PRELIMINARY FLIGHT EXPERIMENT
Artemiss and BIORAT 1&2 are ISS Experiments
science data collection
technology demonstration
Artemiss
BIORAT 1
BIORAT2
Moon Lander
PHASE 3: GROUND & SPACE DEMONSTRATION
Ground Demonstration
With animal
With Humans
Space
System study
Engineering model
Flight Hardware
Module 1
Module 2

Conclusion

- Very high level of challenges,
- An existing community and 20 years of research,
- Objectives in line with Terrestrial and Space R&D evolution,
- Need to enlarge the MELiSSA community with key technical and political leaders, able to share the vision, and the risks.