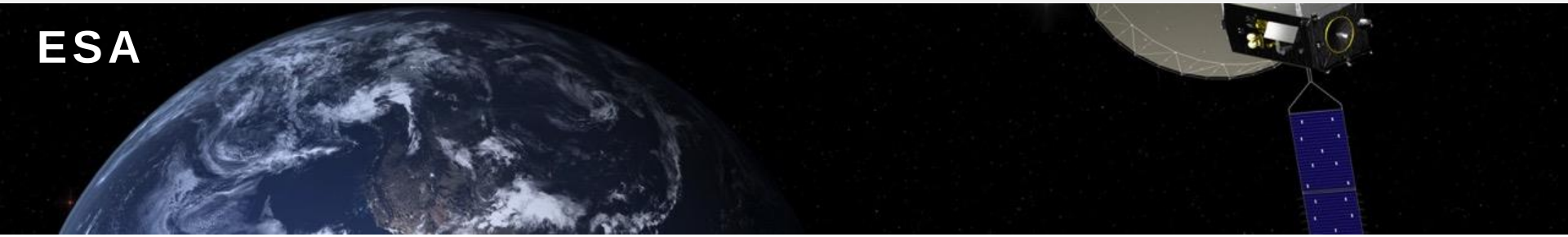
MELiSSA

The European Project of Closed Life Support System

Ch.Lasseur, JAXA, January 17th, 2017

ESA



EUROPEAN SPACE AGENCY

- founded in 1975
- executes European space policies
- 22 member states
- cooperation with NASA, Russia, Japan et cetera
- yearly budget > 4.4 miljard EURO
- ESTEC/ESA: largest research facility (Noordwijk, The Netherlands)
- approx. 2700 highly educated scientists

INTRODUCTION

ESTEC/ESA NOORDWIJK

ESA astronauts

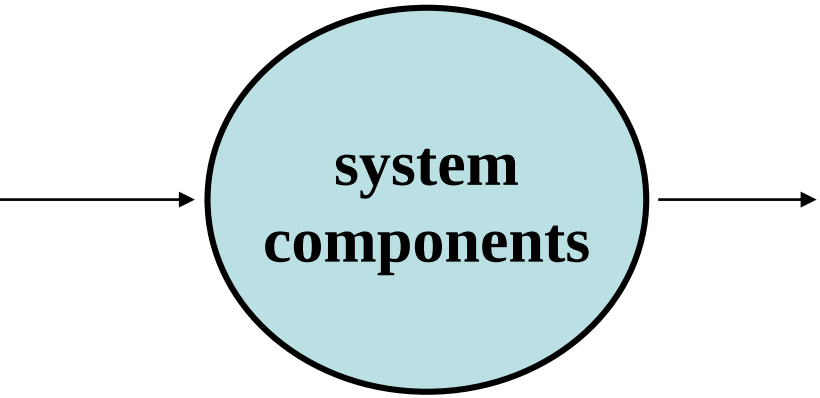
Life Support Functions

- **For the last 30 years ESA studied :**
  - Air Recycling,
  - Water Recycling,
  - Waste Management,
  - Food Production and Preparation,
  - Quality control (chemical and microbiological),
  - Reliability & Safety Issues,
  - Modelling & System tools,
  - Ergonomics &Habitability

FOR ALL THESE FUNCTIONS, PHYSICAL/CHEMICAL/BIOLOGICAL PROCESSES ARE CONSIDERED

Today → Tomorrow

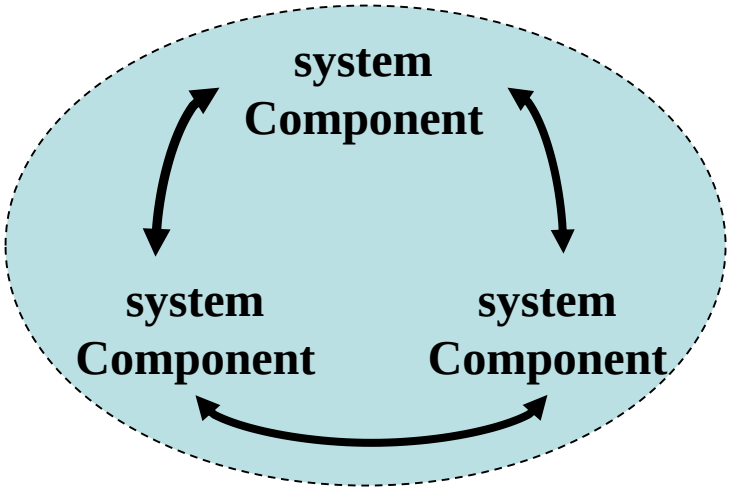
«Juvenile» system



Unlimited Resources

Unlimited Waste

«Mature» system

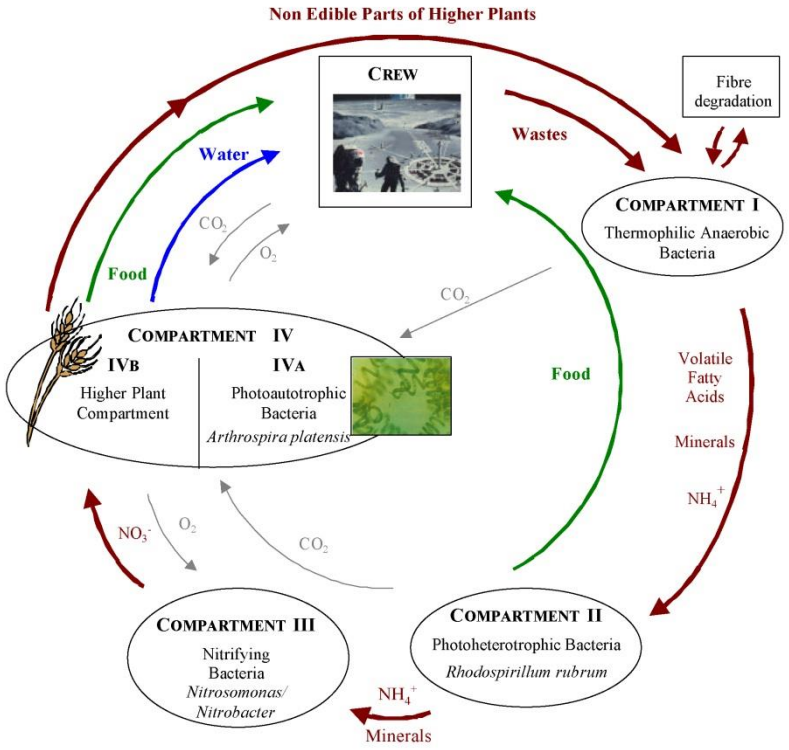


- Low consumption of resources
- Quasi-cyclical flows of materials

ALiSSE Criteria

- Metric to evaluate and compare ECLSS:
  - Multi-parameters,
    - Efficiency,
    - Mass,
    - Energy, **ENRUM study,**
    - Safety,
    - Crew time.

The Concept



A Community

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,
- …..

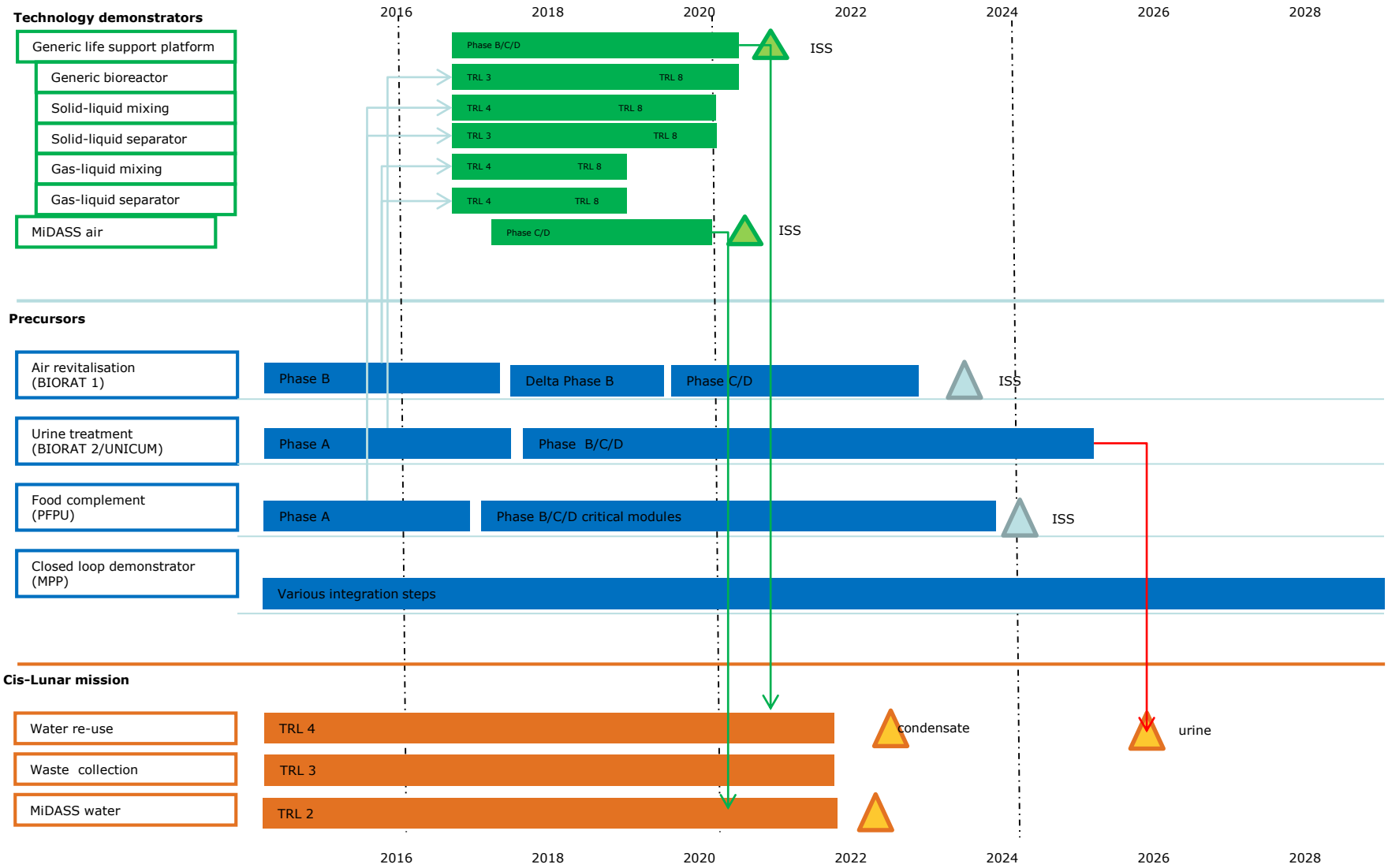
The Technological Challenges

- 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,….

Roadmap



Basic R&D

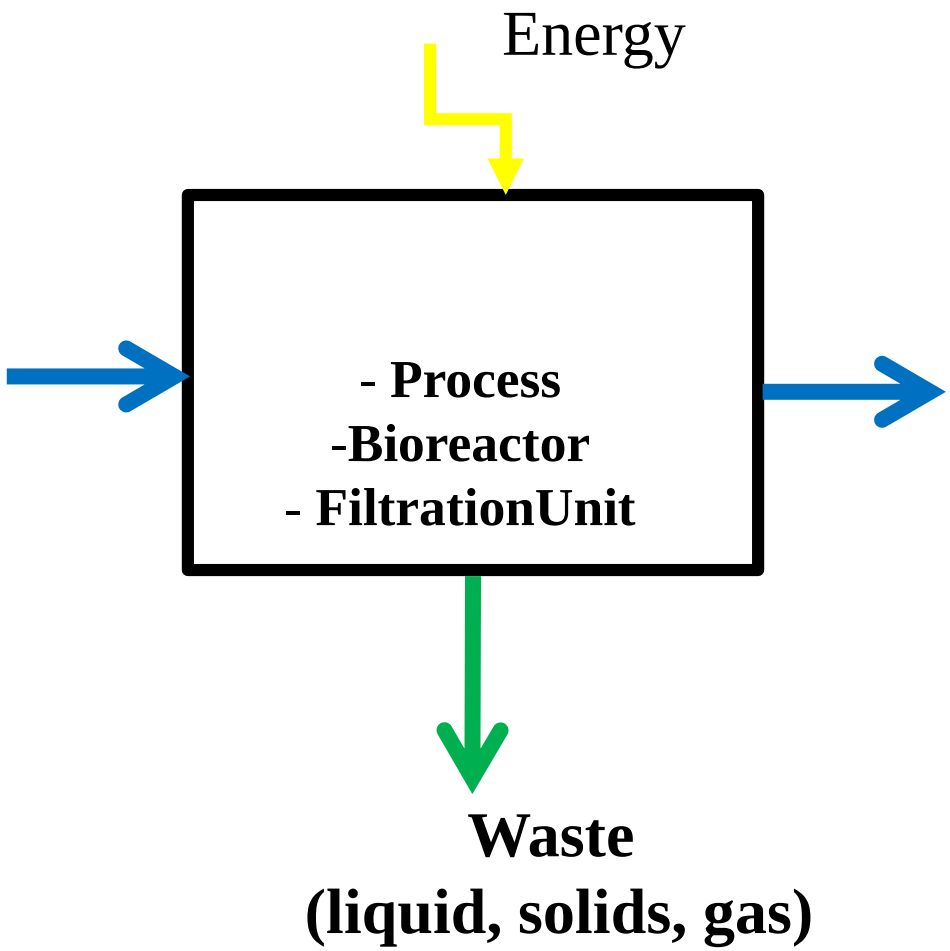
The Modelling Approach

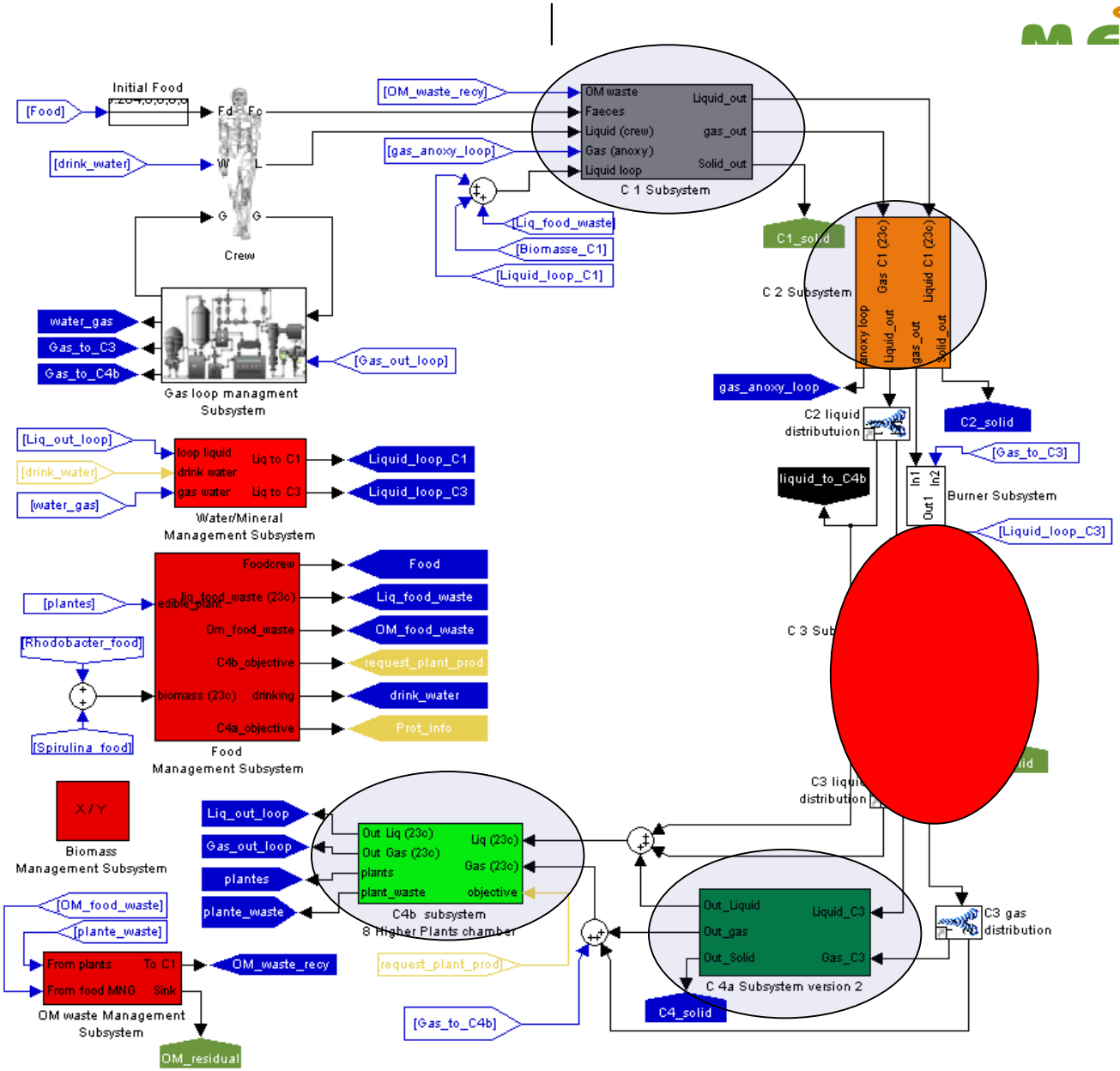
- As mechanistic as possible.

- Requirements implies :
  - Mass balances to be considered : all elements and all phases
  - Energy balances to be considered
  - Rate limiting processes to be characterized
  - Prediction at nominal point
  - Usable for control purposes
  - Prediction at degraded modes.

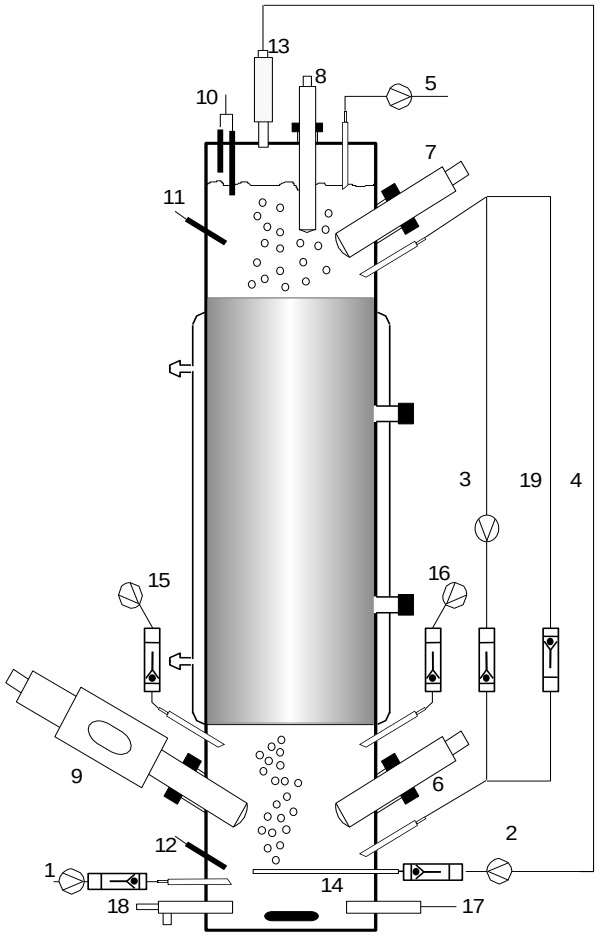
- Even if very challenging, **“we can… because we must”**

The approach Inputs / Outputs





Nitrogen Transformation



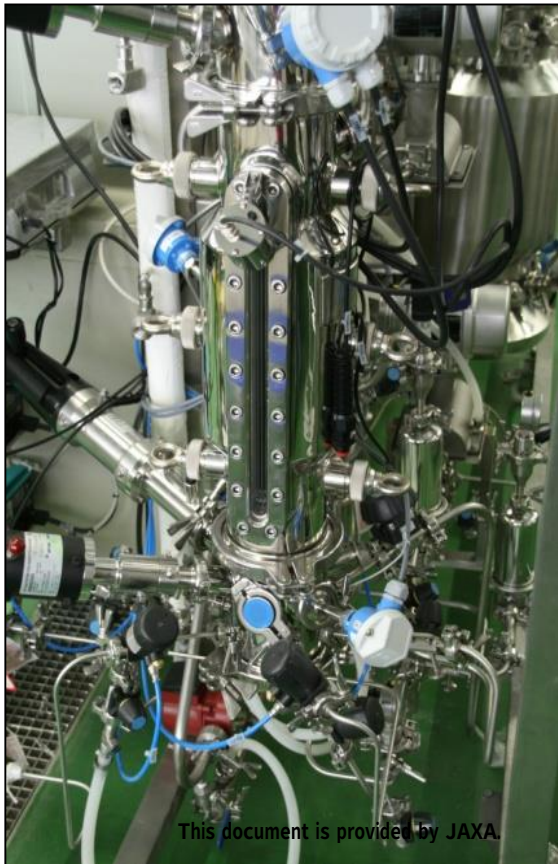
NH_4^+ → COMPARTMENT III → NO_3^-

Nitrobacter winogradskyi

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

Nitrosomonas europaea

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



Modeling the third compartment

Model calibration/validation

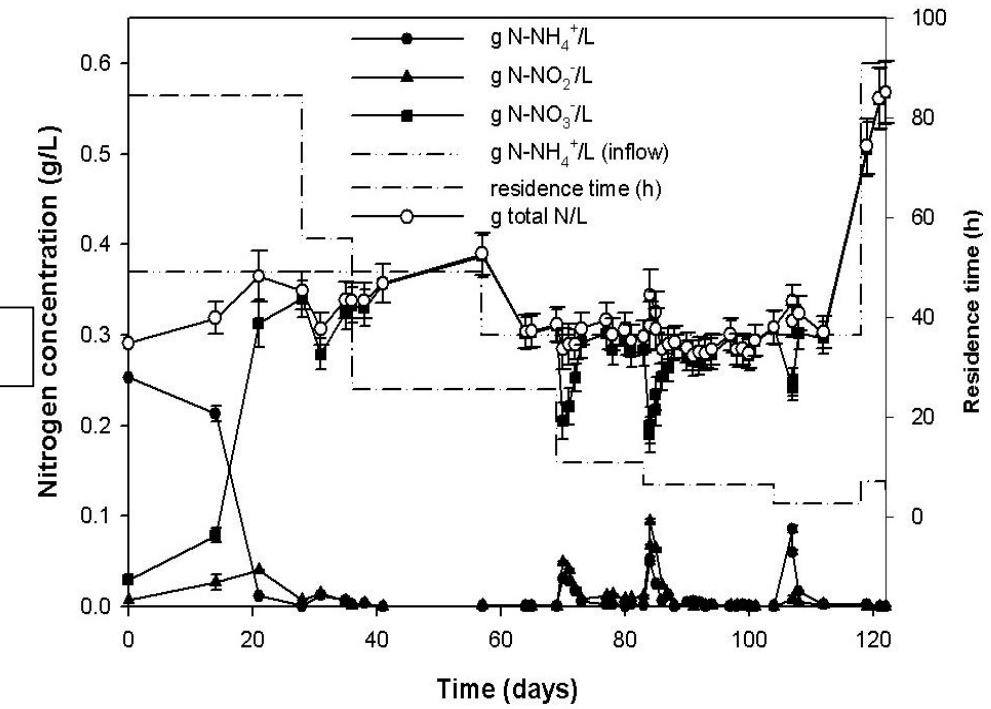
Biological parameters:

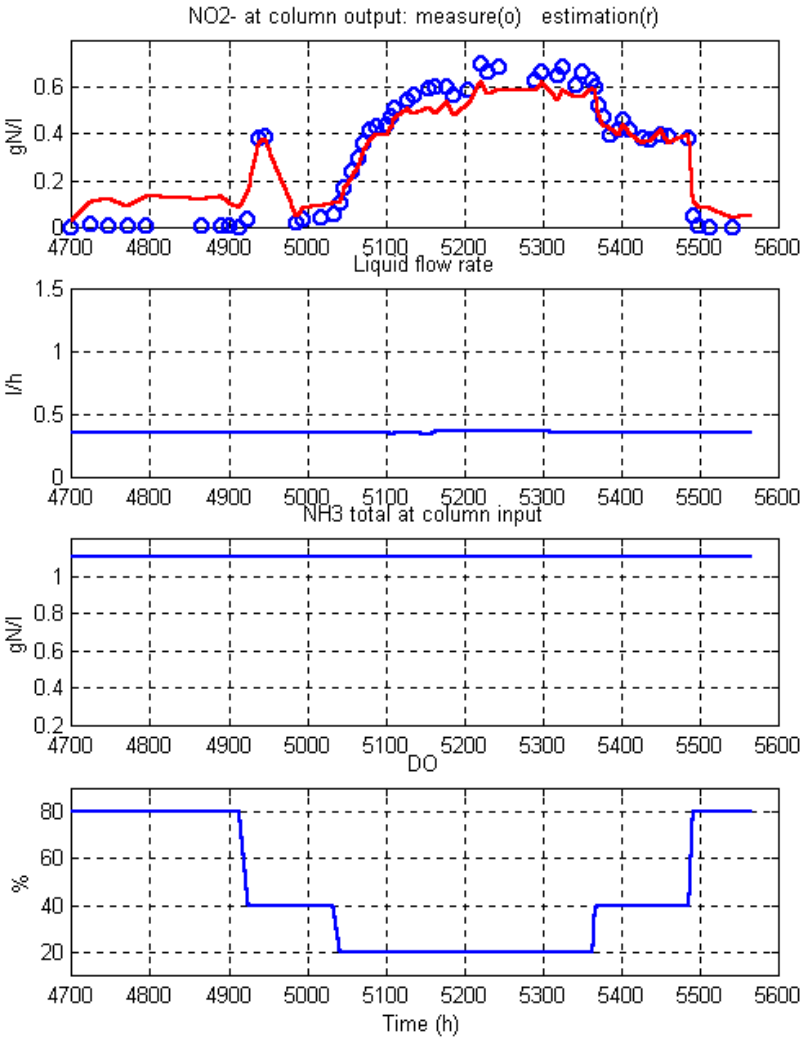
- Pures cultures (batch reactors)
- Coculture (fixed-bed reactor and bioreactors

Physical parameters:

- DTS: characterisation of the hydrodynamic model
- kLa: characterisation of the gas/liquid transfer rate

High Level of Prediction





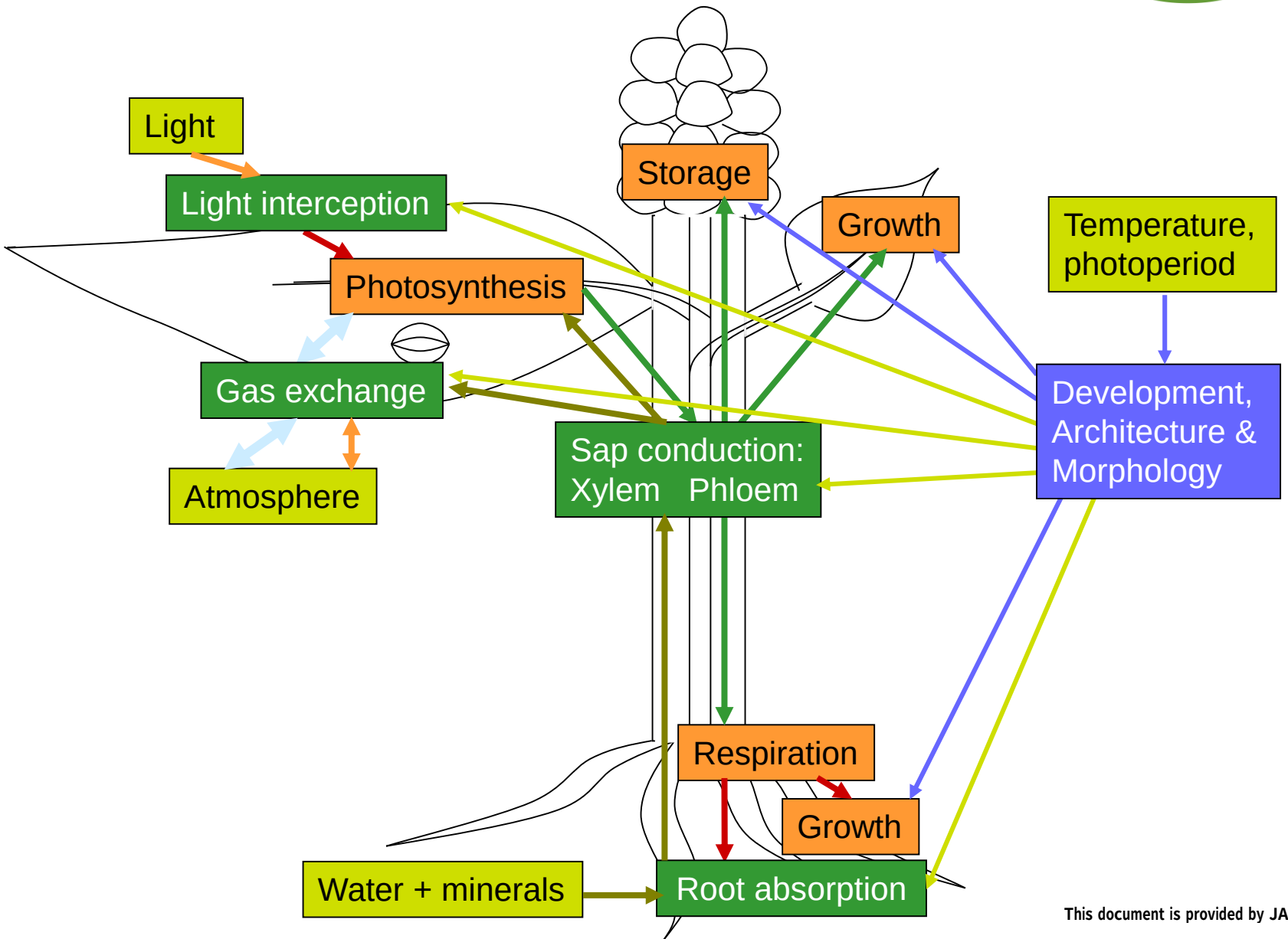
Variation of the Dissolved Oxygen

The Producer

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

Higher Plants Research

Modelling



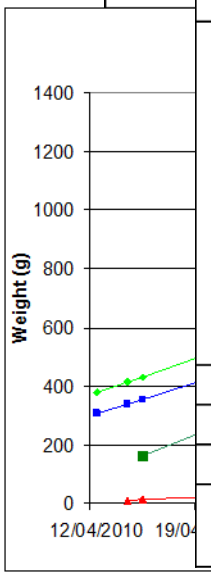
Plant Characterisation Unit preliminary design

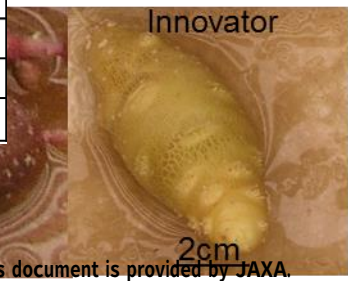
- Objectives:
  - Characterize plant growth (gas exchanges, nutrient uptake, water uptake) under varying environmental conditions including root microbiology
  - Characterize plant composition (chemical and nutritional quality) under varying environmental conditions including root microbiology
  - Develop first principle mathematical model of plant growth
  - Develop predictive control algorithm for optimization and control of the MELiSSA Higher Plants Chamber

Crop cultivar test

		Annabelle	Bintje	Desiree	Innovator
Tuber	HZPC 2008	2.5		1.53	0.9
					0.74
					0.501
					1.05
					0.355
					0.83

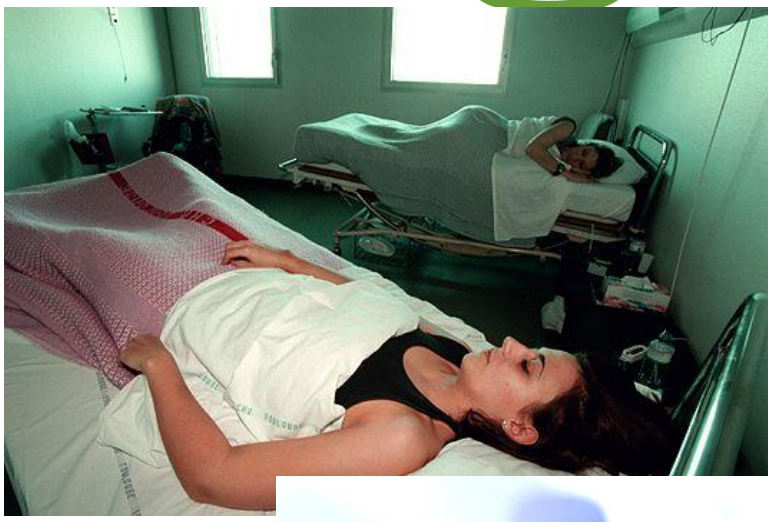
		Hydroponic				Field			
BT2 UGent		Annabelle	Bintje	Desiree	Innovator	Annabelle	Bintje	Desiree	Innovator
Water (%)		78,2	81,1	84,2	77,9	81,8	76,5	79,7	77,6
Protein (%)		1,62	1,20	1.58	1,39	1,33	1,57	1,49	1,43
Fat (%)		0,06	0,04	0.08	0,04	0,07	0,08	0,07	0,07
Available carbohydrates (%)		14,23	14,40	10.79	14,15	14,42	18,75	15,98	17,92
Total Dietary Fibers (%)		1,53	1,80	2.2	1,79	1,66	2,14	1,86	2,09
Minerals (%)		1,16	1,18	1.13	1,08	0,75	0,93	0,87	0,9
Of which (mg/ 100g)	Potassium	504	507	477	440	432	248	234	192
	Calcium	5,5	7,5	7.4	8,7	16,4	21	22,9	14,9
	Magnesium	29,4	22,2	22.6	26,7	20,6	17	21,2	19,3
	Iron	0,7	0,8	0.4	0,6	1,9	2,5	4,7	2,4
	Copper	1,1	0,5	0.7	0,8	0,3	0,4	0,16	0,3
	Zinc	1,1	0,9	1	1,9	0,3	0,2	0,4	0,26
	Manganese	0,18	0,11	0.13	0,13	0,15	0,11	0,13	0,1
	Phosphorus	108	87	89	90	32	23	34	28
Solanine (mg/kg)		0	0	0	0	0	4	0	-
Chaconine (mg/kg)		0	0	0	0	0	24	0	-
Energy (for 100g)	kcal	67,0	66,4	54.6	66,1	86,3	74,3	72,3	58,3
	kJ	280,1	277,8	228.4	276,8	361,1	310,7	302,5	244,1

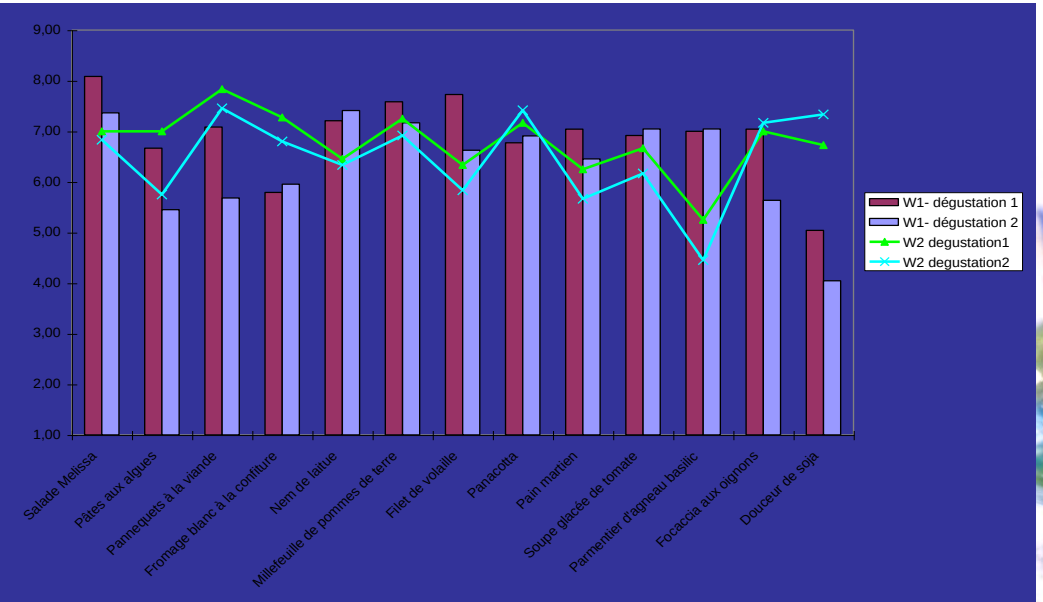




Participation in Bedrest

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

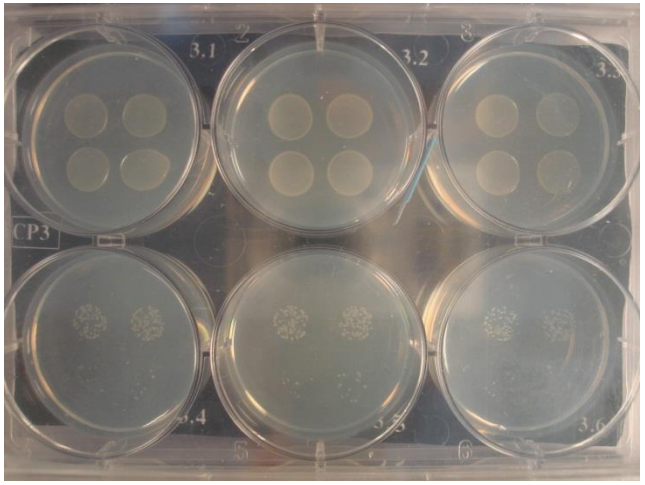




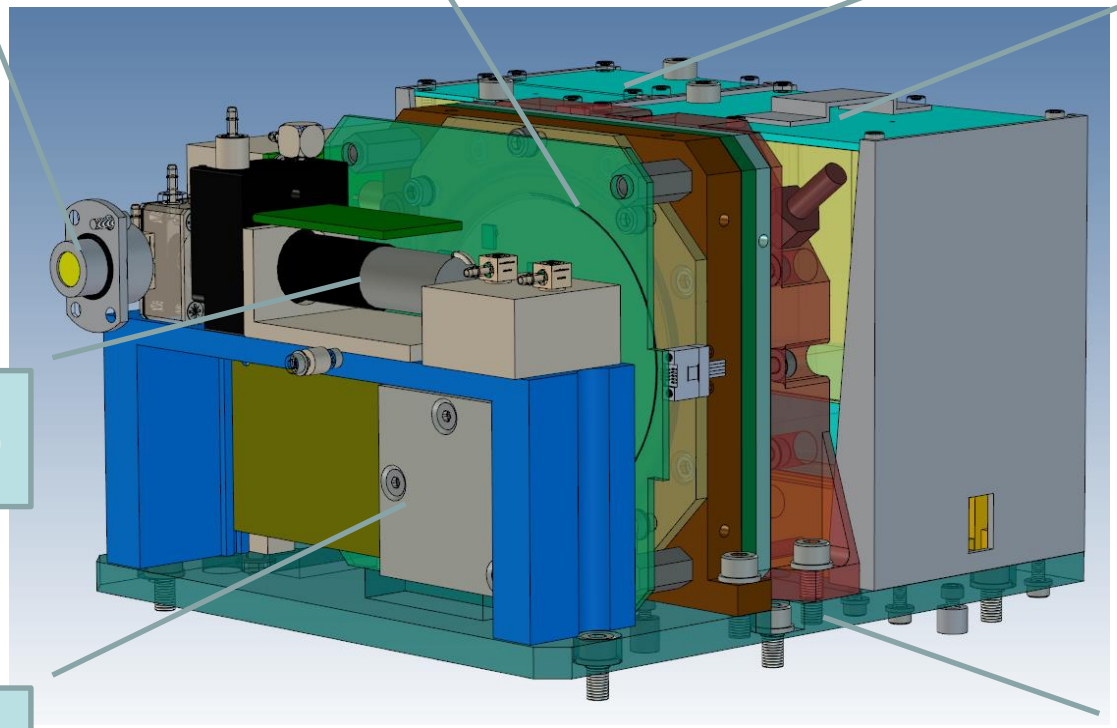
Preliminary Space Experiments

Regularly in Space

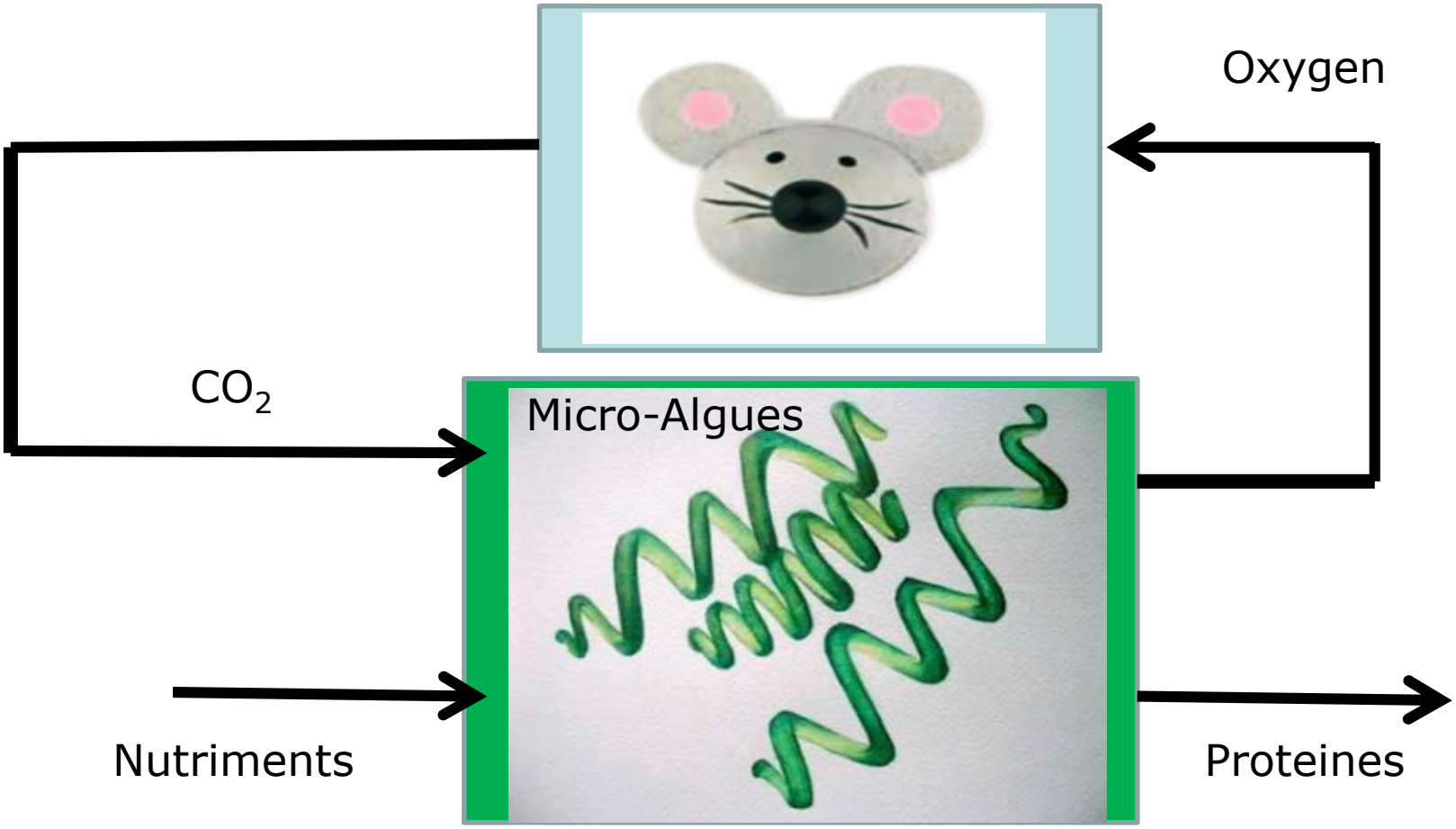
- MESSAGE 1: October 2002
- MESSAGE 2: October 2003
- BASE: September 2006/October 2009
- NITRIMEL: August 2014
- DEMES & BISTRO: September 2015
- ARTEMISS: Falls 2017.



ARTEMISS- In ISS September 2017



Oxygen/CO_2



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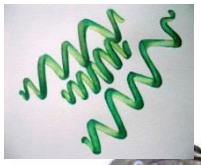
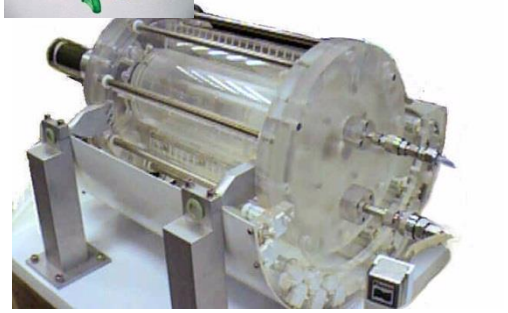
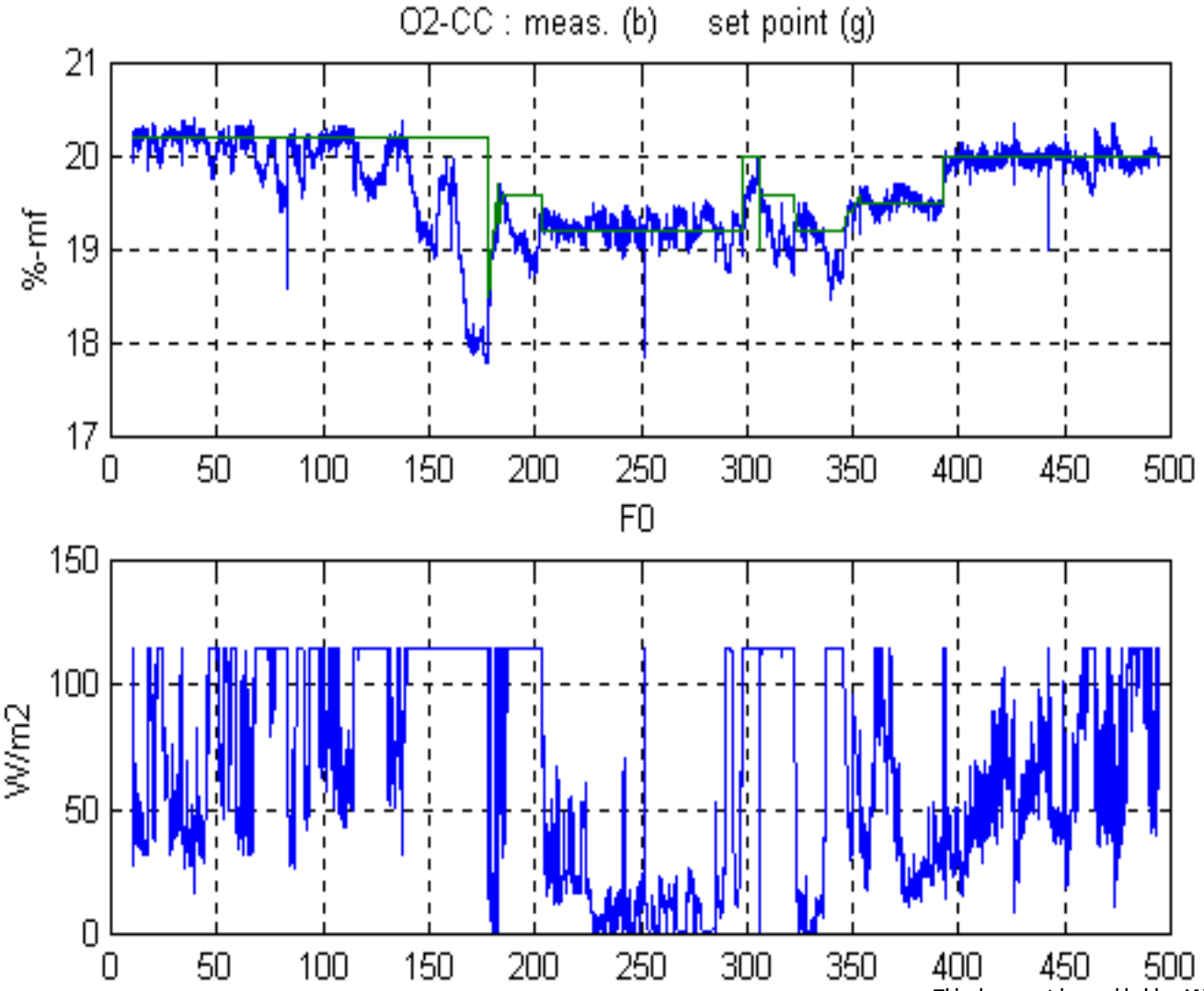






Integration for Ground Demonstration

Concordia Station

Altitude: 3233 m

Thickness ice layer: 3300 m

Distance from sea: > 1000km

Summer T°: - 30°C

Winter T°: - 60°C

Minimum T°: - 80°C

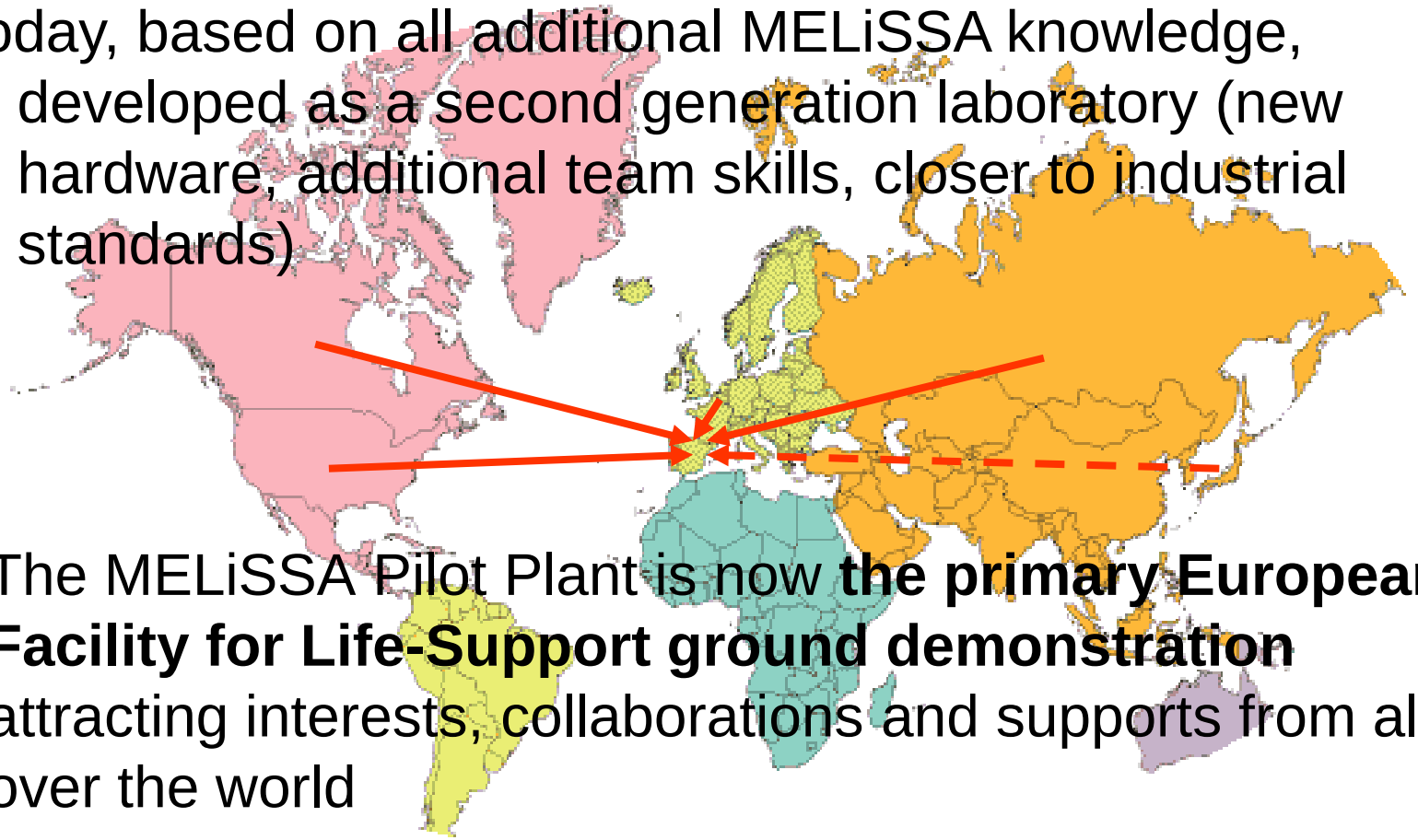
Atmospheric pressure: 645 hPa

French settlement

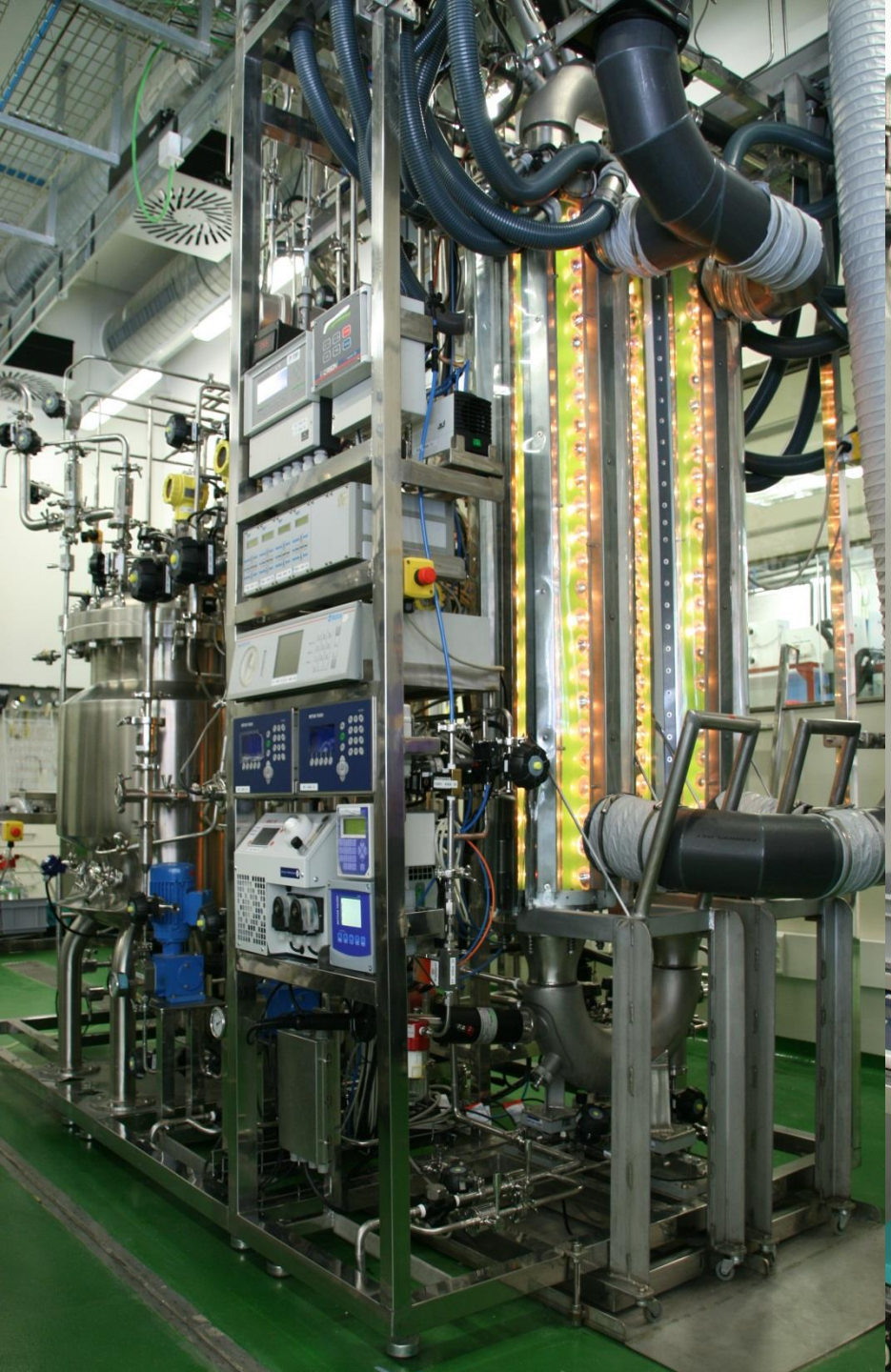
Construction plan carried out by the French-Italian joint (IPEV-PNRA)

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)



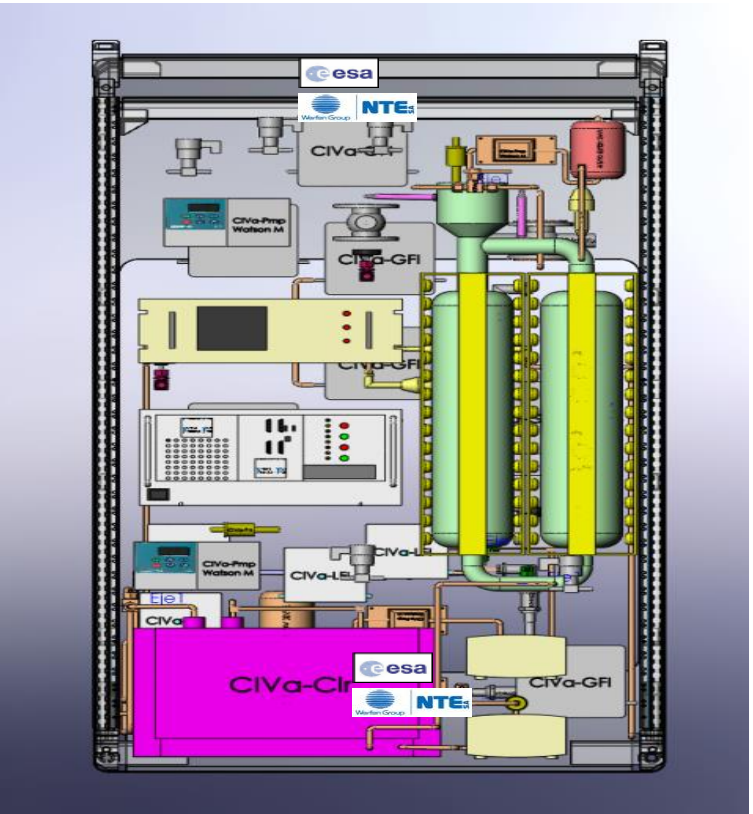
The MELiSSA Pilot Plant is now **the primary European Facility for Life-Support ground demonstration** attracting interests, collaborations and supports from all over the world

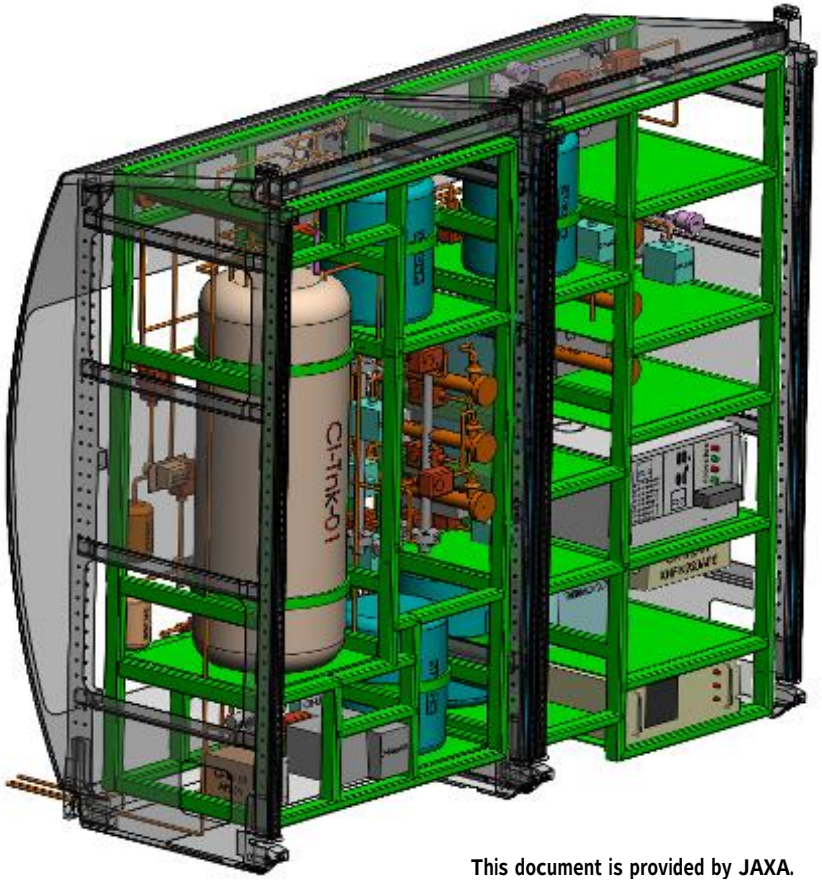


Space Design

– Preliminary sizing

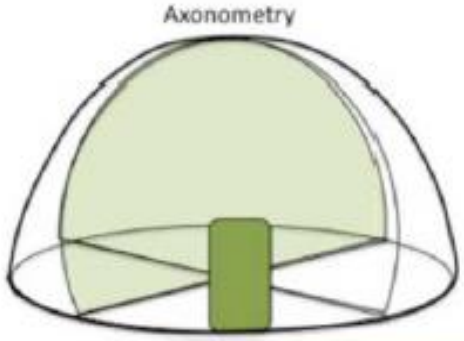
– System studies





PS selected concepts for further analysis

1 – INFLATABLE DOME – ONE MEMBRANE

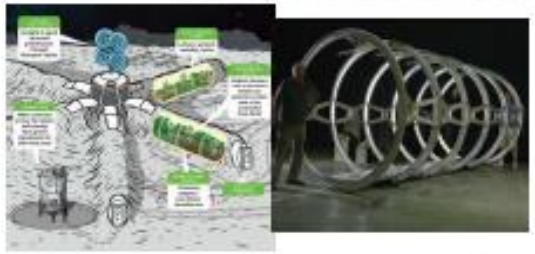


SICSA MarsLab Concept [2004]

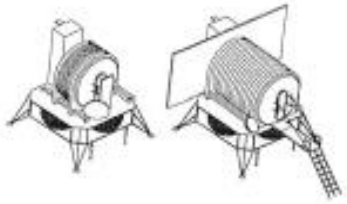
SICSA LunarHab Concept [1980]

2 – INFLATABLE CYLINDER W. INT. STRUCTURE

LGH Arizona University [on-going]



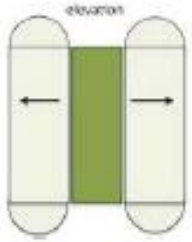
NASA/ILC Lunar Habitat [1996]



TASI/Aero Sekur STEPS2 [on-going]

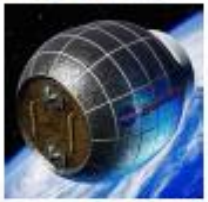
THALES ALENIA SPACE INTERNAL

3 – INFLATABLE CYLINDER W. INT. RIGID CORE



NASA/ILC Dover/TASI TransHab [2000]

NASA/Bigelow Genesis I, II and BEAM [on-going]



ESA/TASI/ Aero Sekur IMOD [2006]

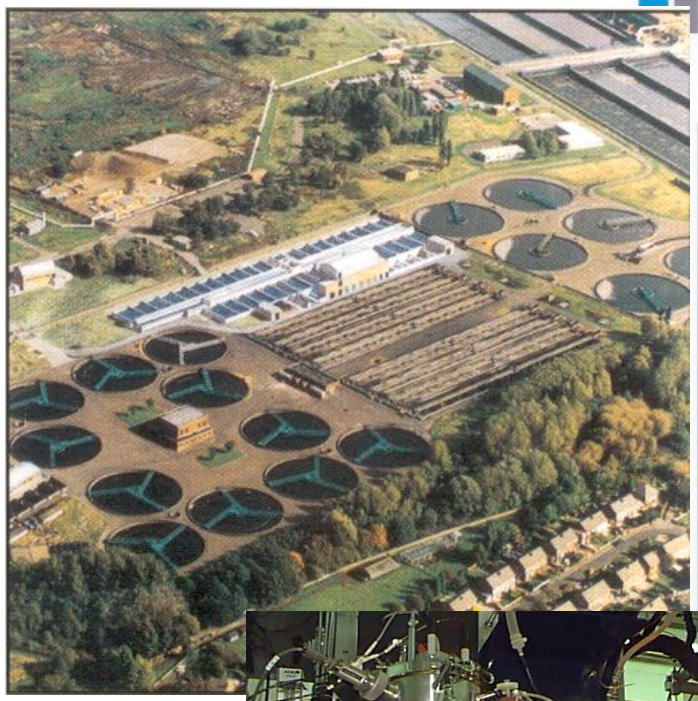
Thales

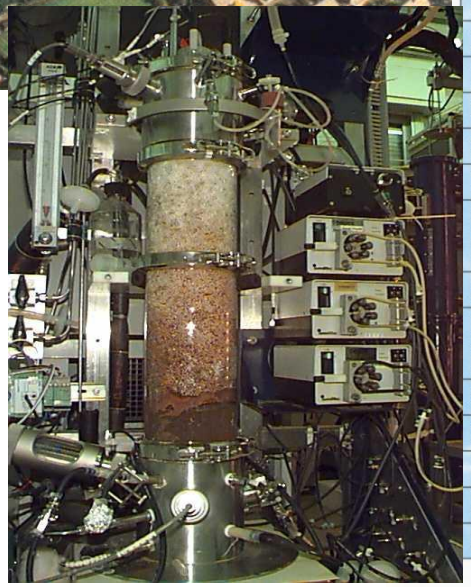
Terrestrial Interest

Quelques référenc

BIOSTYR

EAUX USÉES





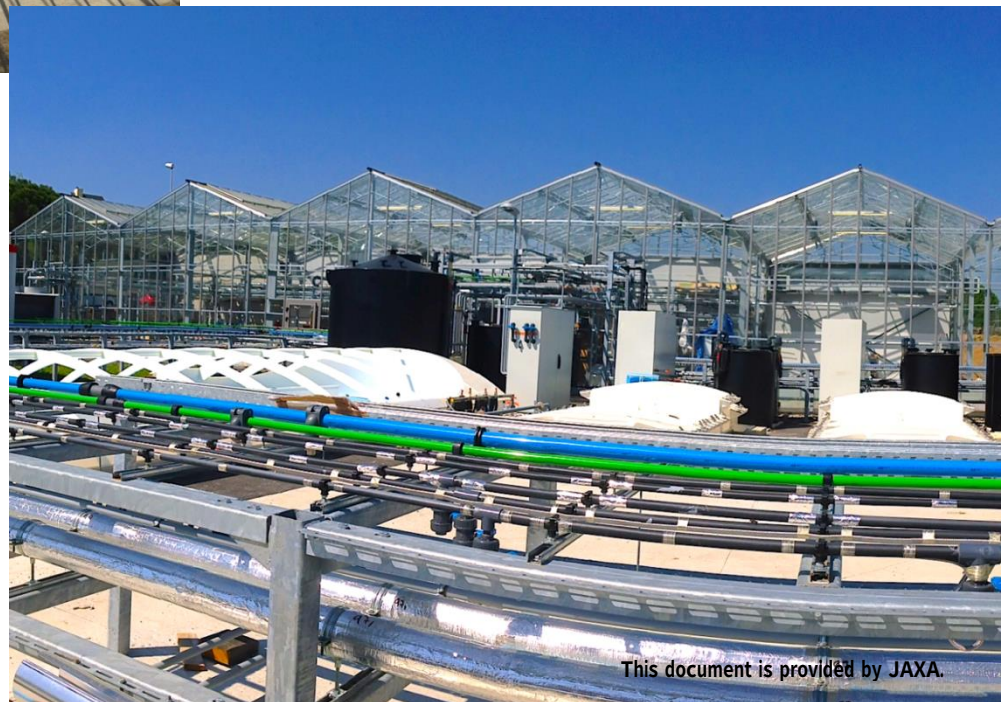
SITE	PAYS			
ST THIBAULT DES VIGNES LAGNY T4	FRANC			
PIAN SCAIROLO	SUISS			
DAVYHULME - MANCHESTER	GRANDE-BRE			
COLOMBES - PARIS	FRANC			
FRIELAS	PORTUGAL	1998	97 200	Elimination de la pollution carbonée
COLOMBIER	SUISSE	1998	18 000	Elimination de la pollution carbonée
ALTENRHEIN	SUISSE	1998	13 500	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

Microbial Safety: MiDASS

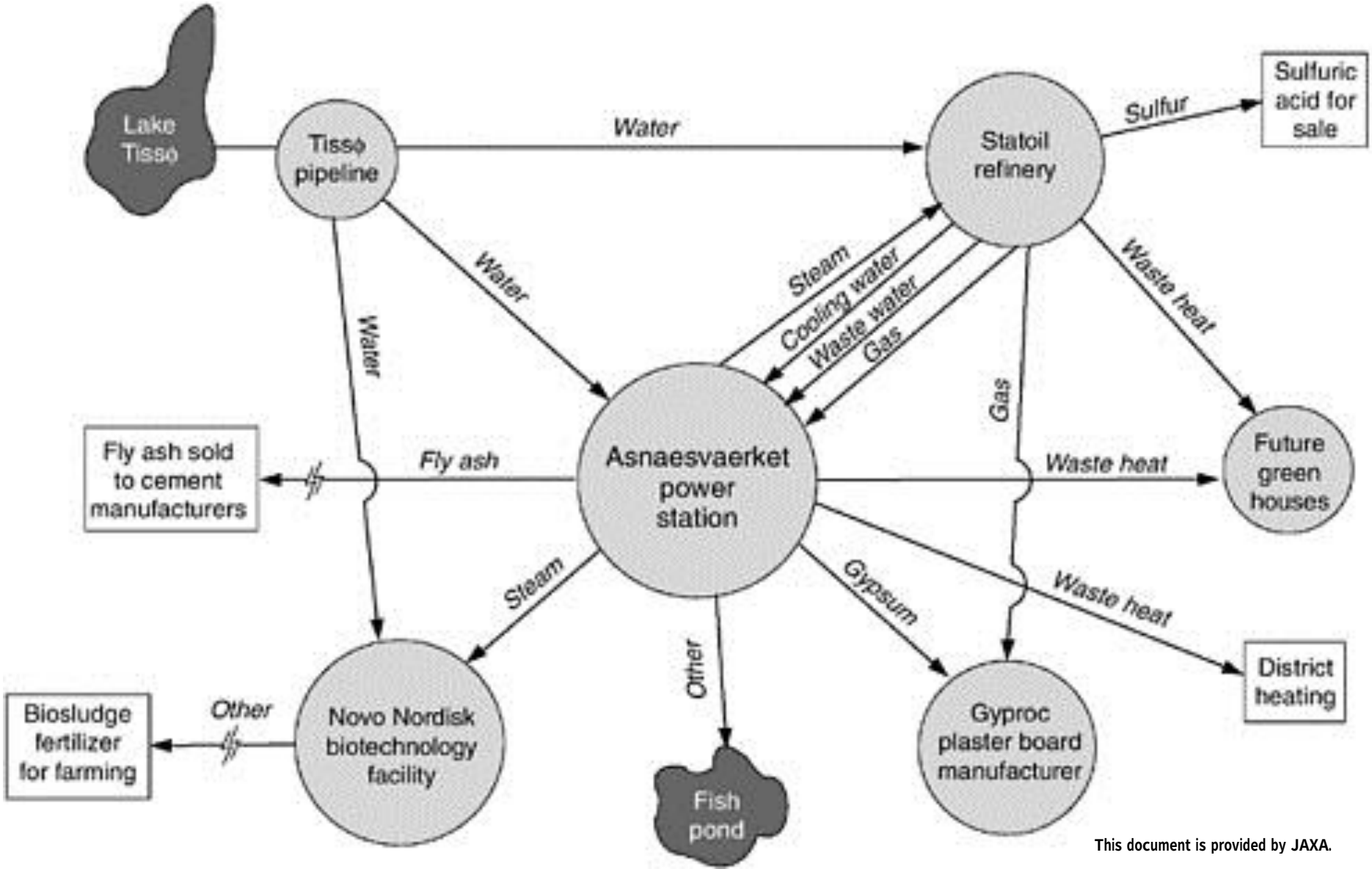
- Fast Microbial Identification and quantification <3 hours
- Pan fungi, pan bacteria,
- Fully automated,
- Unique technology,
- Large terrestrial market : from hospital to pharmaceutical industry
- 50/50% investment with private industry

ALGOSOLIS



Green Building
XTU Initiative

Industrial Ecology ?



Conclusion

- Very high level of challenges,
- An existing community and 27 years of research,
- Objectives in line with Terrestrial and Space R&D and evolution, (e.g. Circular Economy),
- Very much open for collaboration.