Introduction to MELiSSA Project

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Mass Balance

**Inputs:**
- $O_2$
- Water
- Food

**Outputs:**
- Urine
- Feaces
- CO$_2$
- Transpiration
- Contaminants (Microbial Chemical)
Some Basic Calculations

• Metabolic Consumables:
  • For 5kg/d/pers, 6 crew members, 1000 days missions (Mars)
    \[\rightarrow 30\,000 \text{ kg},\]

• Including hygiene items:
  • Same mission configuration (+20kg/water/d)
    \[\rightarrow 132\,000 \text{ Kg},\]

But current launcher can only drop 9 t on the Moon !!!!
Today: Open System (i.e. juvenile)
Tomorrow: Closed (i.e. mature)

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

How to assemble processes and technology to reach the highest possible level of closure and the best set of ALiSSE Criteria.
ALiSSE Criteria

- Metric to evaluate and compare ECLSS:
  - Multi-parameters,
    - Efficiency,
    - Mass,
    - Energy,
    - Safety,
    - Crew time.
The Food issue

• No high degree of closure without Food production,
• Food means Biological processes,
• Biological process means:
  • Complex molecule (>>>>> O2 or H2O),
  • Very high and very slow dynamics,
  • Potential nature changes,
• So far, same logic applies for waste recycling !!
MELiSSA Project

- Started in 1989
- ~30 organisations,
- 14 countries (this morning.....)
A Team Work
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,
- …..
Step by Step
LAVOISIER’ approach
LAVOISIER’ approach

Energy

Process 1

WASTE

C, Umx1, Kl1, Kx1, Hy1
H, Umx2, kl2, kx2, Hy2
N, Umx3, Kl3, Kx3, Hy3,
O
P
S
.
LAVOISIER’ approach

Process 1

Energy

C, Umx1, K11, Kx1, H1
H, Umx2, k12, kx2, H2
N, Umx3, K13, Kx3, H3,
O………………………
P………………………
S ……………………….
………………
LAVOISIER’ approach
LAVOISIER’ approach
LAVOISIER’ approach
LAVOISIER’S approach

C, Umx1, KI1, Kx1, Hy1
H, Umx2, kI2, kx2, Hy2
N, Umx3, KI3, Kx3, Hy3,
O
P
S
.
LAVOISIER’ approach

Energy

Process

2

C, Umx1, K11, Kx1, Hy1
H, Umx2, k12, kx2, Hy2
N, Umx3, K13, Kx3, Hy3,
O
P
S
.
LAVOISIER’ approach

Energy

Process

C, Umx1, Kx1, Hy1
H, Umx2, kx2, Hy2
N, Umx3, Kx3, Hy3,
O........................
P........................
S..........................
...
C, Umx1, Kx1, Hy1
H, Umx2, kx2, Hy2
N, Umx3, Kx3, Hy3,
O........................
P........................
S..........................
...


LAVOISIER’ approach

Energy

Process

2

C, Umx1, Kl1, Kx1, Hy1
H, Umx2, kl2, kx2, Hy2
N, Umx3, Kl3, Kx3, Hy3,
O……………………
P……………………
S……………………

C, Umx1, Kl1, Kx1, Hy1
H, Umx2, kl2, kx2, Hy2
N, Umx3, Kl3, Kx3, Hy3,
O……………………
P……………………
S……………………

Modelling and Simulation Approach

• From one microorganisms modelling to a functional community modelling,
• From CHNOS to the “complete” Mendeleev table,
• From Mass balance/Monod to Thermodynamical models (i.e R. Clausius),
• Modelling of genetic/transcriptomic evolution,
Urine: Any Interest?

• Potential Interest depending of the space mission:
  • Water,
  • Nitrogen gas (N2),
  • Nitrates,
  • Energy.

• As well as for Earth: Reduced Environmental Impact with Green algae, odors, pharmaceuticals, hormones,…
Nitrogen Transformation

Nitrobacter winogradskyi

\[ \text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^- \]

Nitrosomonas europaea

Packed-bed reactors
Immobilized cells

Pilot scale reactors
Several reactors

Biofilm control
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
N-tanks in series

Mass balance equation:

$$\frac{d(VL_n S^n)}{dt} = \left( F_{IN} + F_{RECY} + F_{BACKMIX} \right) \left( S^{(n-1)} - S^n \right) + F_{BACKMIX} \left( S^{(n+1)} - S^n \right) \left\{ \text{(in-out) mass flow} \right\}$$

$$+ VL_n RLs^n + VL_n RFs^n \left\{ \text{Bioreaction (Pirt model)} \right\}$$

$$+ VL_n EGLs^n \left\{ \text{Gaz/liquid exchange ratio} \right\}$$
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

- Light
- Atmosphere
- Water + minerals
- Temperature, photoperiod
Modelling

Light

Atmosphere

Water + minerals

Temperature, photoperiod

Development, Architecture & Morphology
Modelling

Light interception

Gas exchange

Atmosphere

Sap conduction: Xylem Phloem

Temperature, photoperiod

Development, Architecture & Morphology

Water + minerals

Root absorption
Modelling

Light

Atmosphere

Water + minerals

Temperature, photoperiod

Storage

Growth

Growth

Respiration

Development, Architecture & Morphology

Sap conduction: Xylem, Phloem

Gas exchange

Light interception

Photosynthesis

Root absorption

Root absorption
Participation in Bedrest

✓ 24 subjects (women).
✓ 3 groups: Controls - Exercise - Nutrition.
✓ Duration: 106 days for each successive period
From Bench Scale to Flight Hardware
Scale Up, then Down, then Up
Scale Up, then Down, then Up
Scale Up, then Down, then Up
Scale Up, then Down, then Up
### PS selected concepts for further analysis

<table>
<thead>
<tr>
<th>Concept</th>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 - INFLATABLE DOME - ONE MEMBRANE</strong></td>
<td><img src="image1.png" alt="Axonometry" /></td>
<td>SICSA MarsLab Concept [2004]</td>
</tr>
<tr>
<td><strong>2 - INFLATABLE CYLINDER W. INT. STRUCTURE</strong></td>
<td><img src="image2.png" alt="Section" /></td>
<td>LGH Arizona University [on-going]</td>
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<tr>
<td></td>
<td><img src="image3.png" alt="Axonometry" /></td>
<td>NASA/ILC Lunar Habitat [1996]</td>
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<td></td>
<td><img src="image4.png" alt="Axonometry" /></td>
<td>NASA/ILC Dover/TASI TransHab [2000]</td>
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<td></td>
<td><img src="image5.png" alt="Axonometry" /></td>
<td>ESA/TASI/Aero Sekur IMOD [2006]</td>
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<tr>
<td><strong>3 - INFLATABLE CYLINDER W. INT. RIGID CORE</strong></td>
<td><img src="image6.png" alt="Axonometry" /></td>
<td>NASA/Bigelow Genesis I, II and BEAM [on-going]</td>
</tr>
<tr>
<td></td>
<td><img src="image7.png" alt="Axonometry" /></td>
<td>Thales ALENIUS SPACE INTERNAL</td>
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Access to Space
MELISSA Space Flight Experiments

- MESSAGE 1 (ISS) (2002)
- MOBILIZATION 1 (ISS) (2004)
- Nitrimel (FOTON) (2014)
- MELONDEAU, incl BISTRO (ISS) (2015)
- ArtEMISS-B/Arthrospira-B (ISS) (2017?)
- ARTEMISS-C/Arthrospira-C (ISS) (?)
- URINIS (ISS) (?)
- BIORAT-1
- ...
The last one: BISTRO
The Next One: ARTEMISS
Access to Earth
CURRENT PROJECTS

*Biobased* and *circular* economic models in the following sectors:

- **Agro & Food**
- **Life sciences & Health**
- **Water & Waste**
water treatment plants across Europe apply BIOSTYR® technology to treat waste water

Developed by MELiSSA and marketed by Veolia

hundreds of millions of liters of water are treated each year
examples

Kinetra, Morocco

Water treatment plant

- Treatment of highly polluted ground water
- Capacity: 1200 people
- Output: safe potable water
- Low energy consumption
Koningshoeven Abbey - Brewery

Partners:
• Koningshoeven Abbey La Trappe
• Water Board De Dommel
• IPStar / UGent
• BioPolus

Objectives
• Create circular La Trappe Brewery
• Treat Water brewery & household
• initiate experiments
Phasyn project

- Production of PHAs from fermentation by-product (waste water)
- PHAs production modelling
- PHAs best composition evaluation
- PHAs composition tuning
- PHAs processability, physico-chemical properties
- PHAs aditivation

Bioplastic development

Umons – MateriNova

Alpo Project

- Specific Arthospira compound as biostimulant - defense of plants
- Patent
- Foliar spray or soil amendment
- Synergic effect with major commercial product
- Tested in real situation (Industrial Partners)

New biotimulant for plant defense

Umons - MateriNova Greenwin
PROJECTS

SEMiLLA Sanitation Hubs

Mobile sanitation unit:
- sanitation, safe water and essential foods
- Refugee camps
- Residential applications

Partners:
- HAS University of Applied Sciences
- UGent
- IPStar BV
examples

algosolis: an R&D facility dedicated to the development of sustainable microalgae industry

Breakthrough technologies for microalgae culture and algorefinery
Preparing for the Future...
MELiSSA as a tool to promote STEM to youngsters...

e.g. ‘Food from Spirulina’ (2015)
- 1000 experiment kits for teachers & students (12-14 j)
- Inflight call to Samantha Cristofferetti in ISS
Citizen Science

• What?
  • Education project for students (14-18 years) based on plant growth observation and scientific data acquisition
  • Design and construction of education kit (WatchMeGrow kit) to be distributed in schools

• How?
  • Design Co-creation with a group of experts (Hackathon)
  • Prototype production in Fab-Lab (Hackathon)
  • Testing and validation in selected schools
  • Final WatchMeGrow production and distribution

• When?
  • Hackathon 7/8 April 2017

• Where?
  BlueCity (centre for circular economy),
  Rotterdam, Netherlands
Conclusion

• MELiSSA is an European project aiming to gain knowledge and demonstrators of circular system,
• MELiSSA is open to European collaborations,
• After 28 years, the challenges are still very high and it is a very long term effort,
• Terrestrial interest is clearer everyday, and we aim to contribute to the circular economy challenges, including via Education.
MERCI