Advanced Life Support and In Situ Resource Utilisation –State of the Art in Europe

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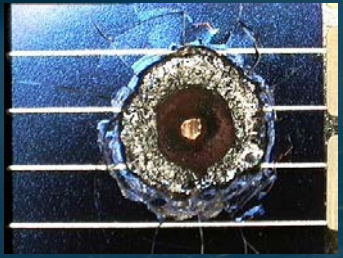
- Life Support, Definition and why we need it
- Traditional Life Support
- Advanced Closed Loop Life Support Systems
- Current activities in ESA/Europe
- In Situ Resource Utilisation: Living off the land
- Application of the Resources
- ISRU processes, state of the art, advantages and disadvantages
- Current efforts in Europe/ISRU Demo Mission

Different environment…still "same" metabolism



7000 >10cm

+120° C

-150° C

Radiation

10^{-11} hPa

Daily Input* /pers.

O_2: 0.9 kg

Water: 3.3 kg

Food: 0.8 kg

TOTAL :~5 kg

10^{-4}g

Daily Output* /pers.

CO_2: 1 kg

Urine: 1.8 kg

Perspiration: 1.8 kg

Faeces: 0.4 kg

Contaminants (chemical & microbial): traces

TOTAL :~5 kg

Life Support System Functions

Life support systems for any crewed space flights include the following functions:

- Air revitalisation
- Potable Water supply
- Wastes management
- Food supply
- Consumables quality control
- Chemical and microbial contaminants control

Traditional Life Support Systems

Traditional Life Support Systems rely heavily on the logistics capabilities and depending on the space vehicle / space mission (Vostok, Salyut, MIR, Mercury Geminy, Apollo, Skylab, Shuttle, ISS):

- Carbon dioxide collected and/or vented
- Oxygen brought from Earth or produced via water electrolysis
- Food brought from Earth
- Water recycled to various levels
- Wastes collected and disposed by return cargo
- Microbial contaminants mostly analysed on ground
- Chemical contaminants

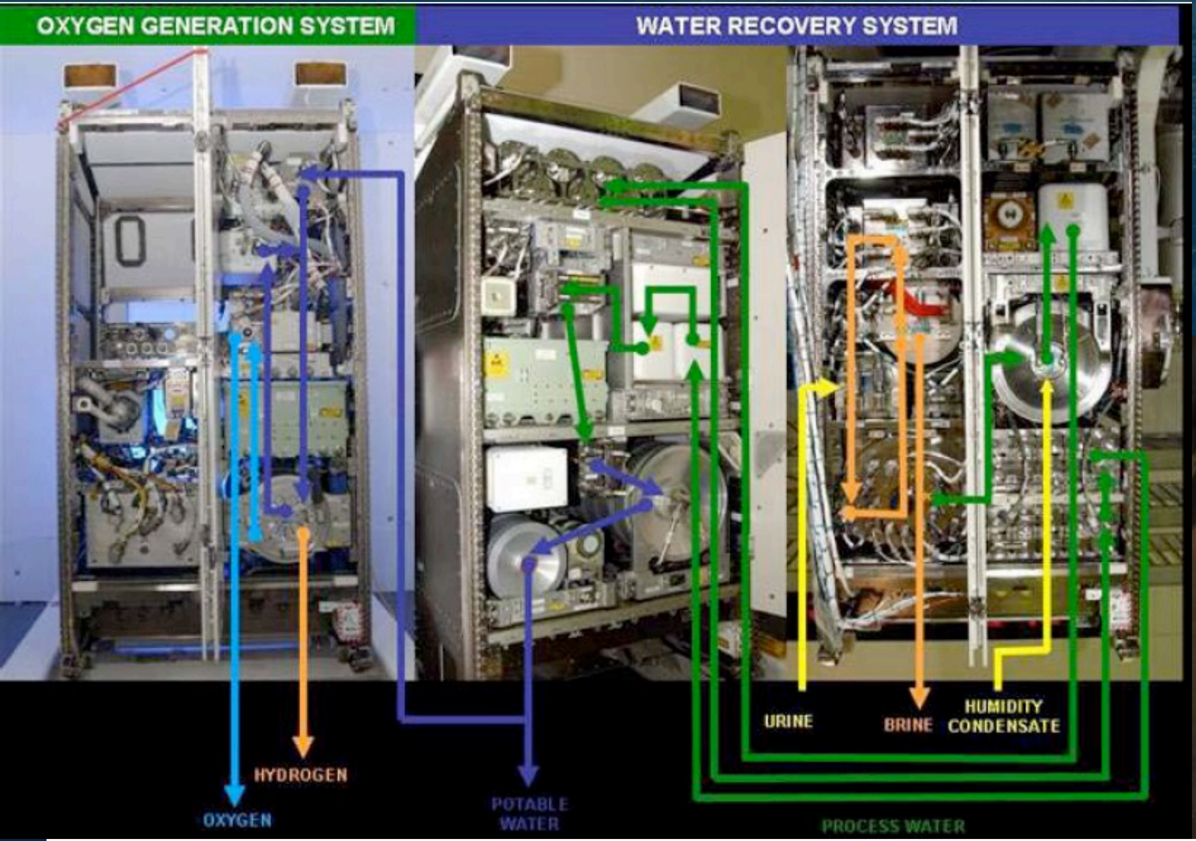
→ limited sustainability and overall resiliency

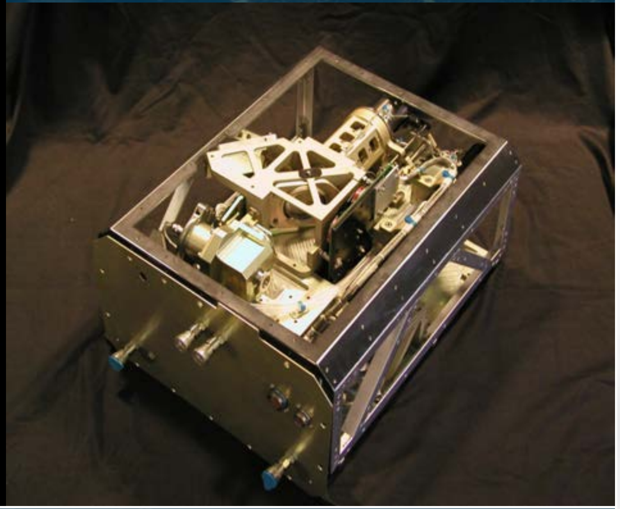
~400 Km

Advanced Life Support Systems

Life Support Systems evolves towards a closed system

- Air revitalisation system targeting CO_2 processing into O_2 (Europe)
- Urine/condensate processing targeting water and oxygen production (US)

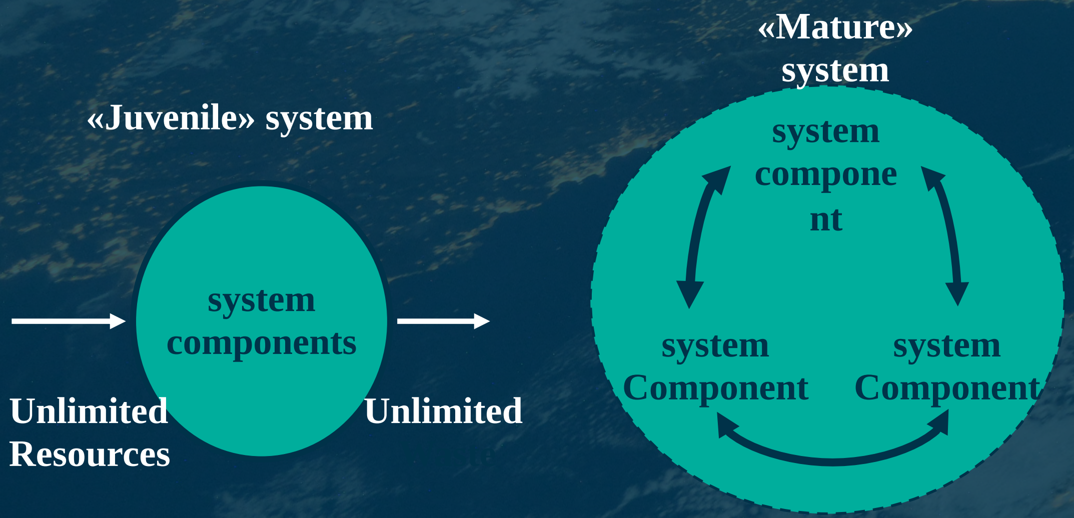


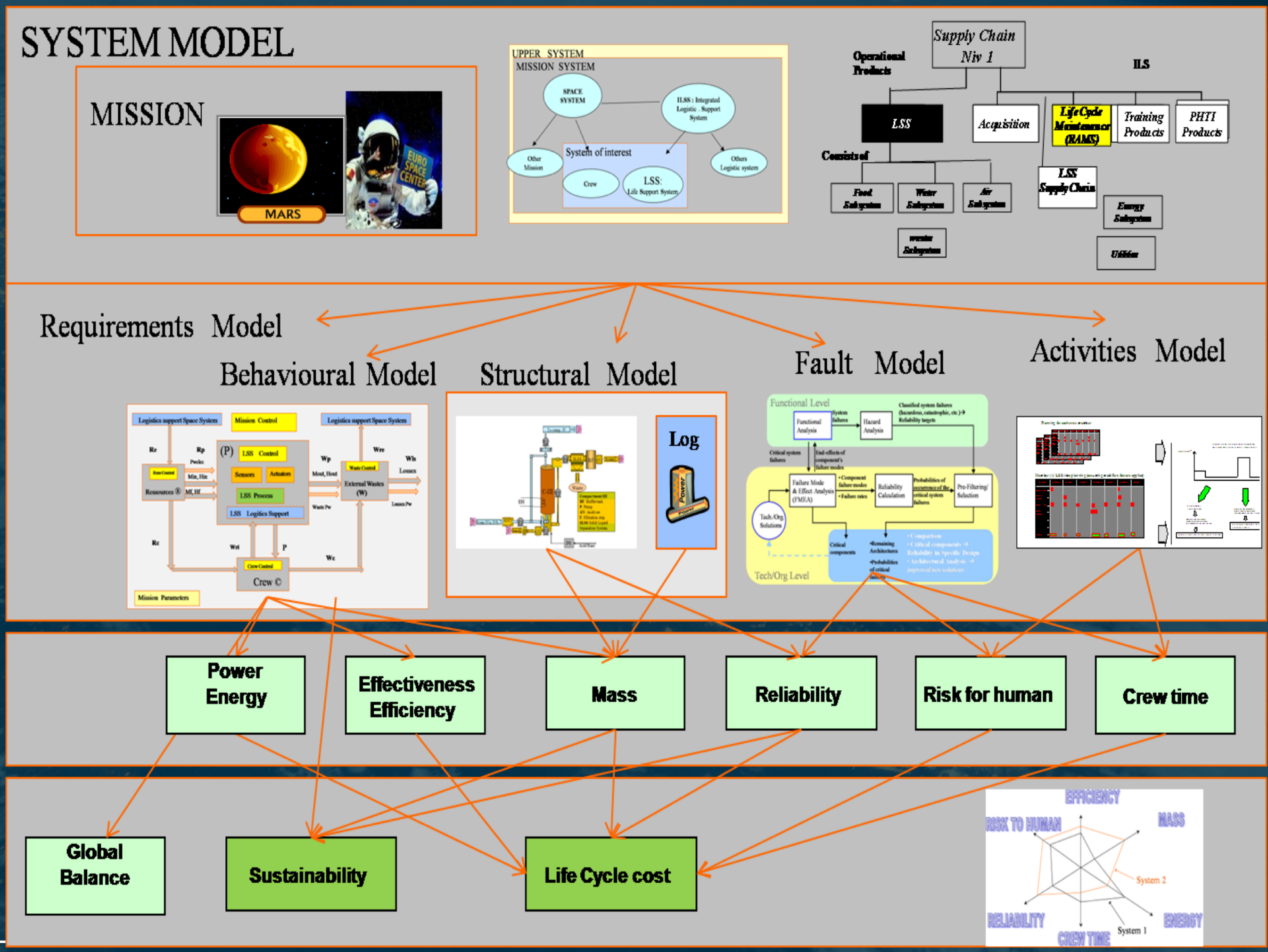


Current activities in Europe

The approach in Europe is strongly directed towards closed regenerative system

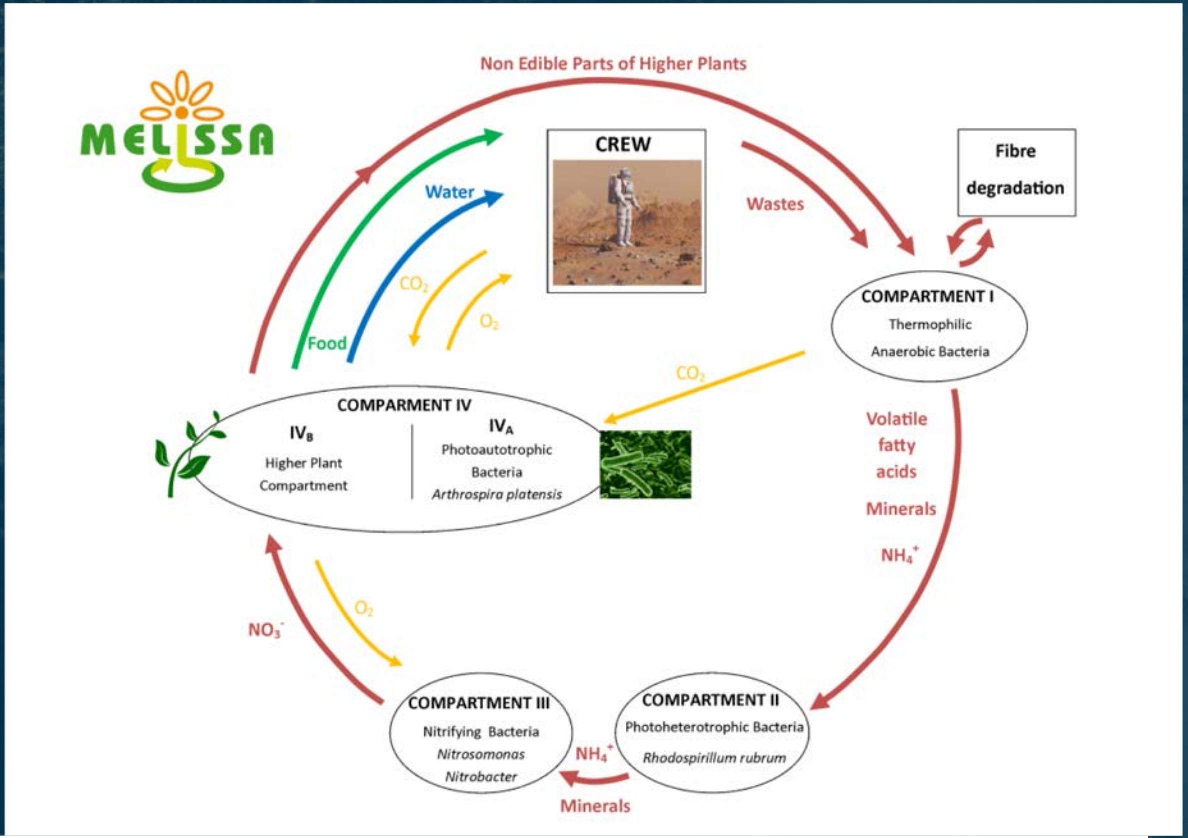
Challenge: assemble the recycling technologies to reach the highest level of closure and the best set of parameters such as mass, efficiency, energy, safety and crew time





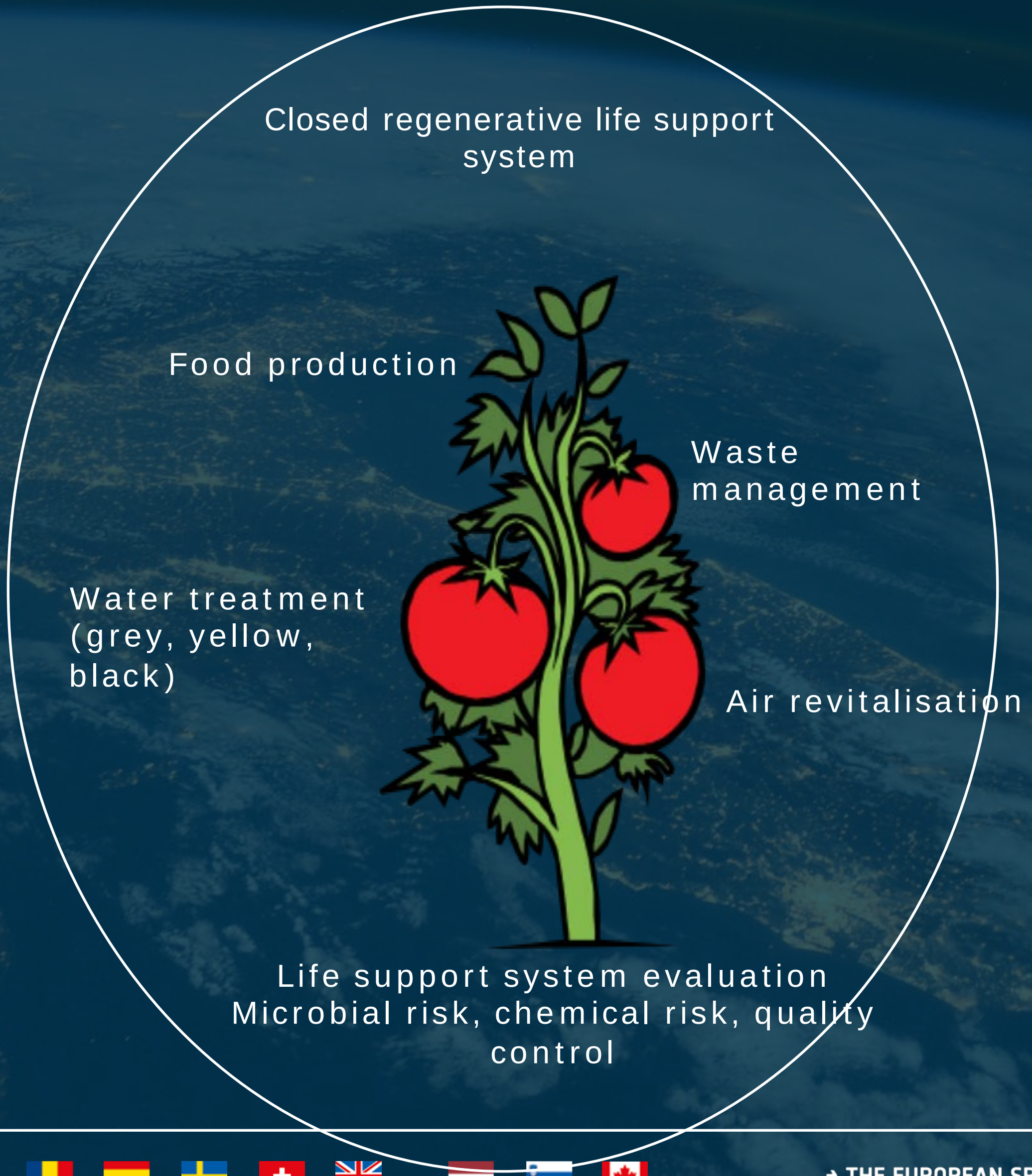
Current activities in Europe: MELiSSA project

- Project initiated in 1989
- Governed by the MELiSSA Memorandum of Understanding (14 Partners)
- More than 40 European organisations, over 12 countries
- Approx. 100 scientists/engineers



MELiSSA technologies development organisation

- Phase 1: Basic R&D
    - System studies,
    - Sub-systems R&D,
- Phase 2: Preliminary Space experiments
    - Scientific data acquisition
    - Technology demonstration
- Phase 3: Ground demonstration/integration
- Education and communication



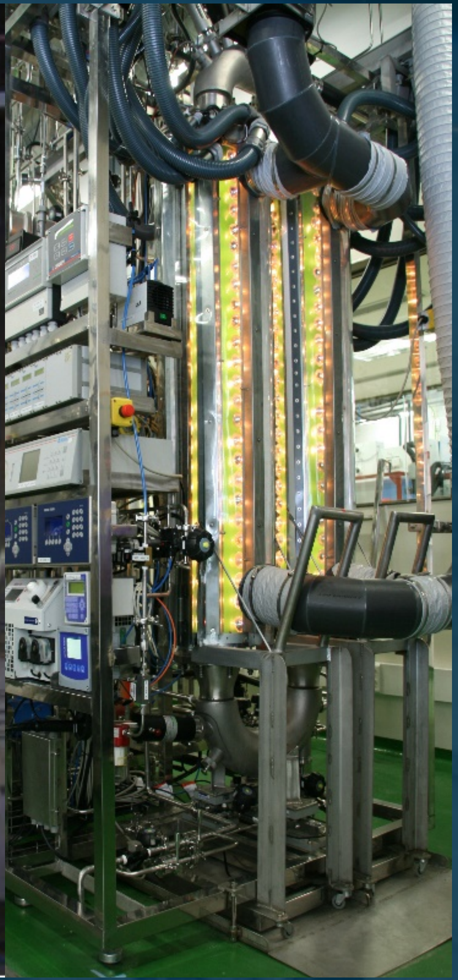
MELiSSA phase 1

Air revitalization function based on cyanobacteria photosynthetic process

Several size and oxygen production capabilities are available

Current work focuses on intensification of volumetric production

Process demonstrated in micro-gravity environment



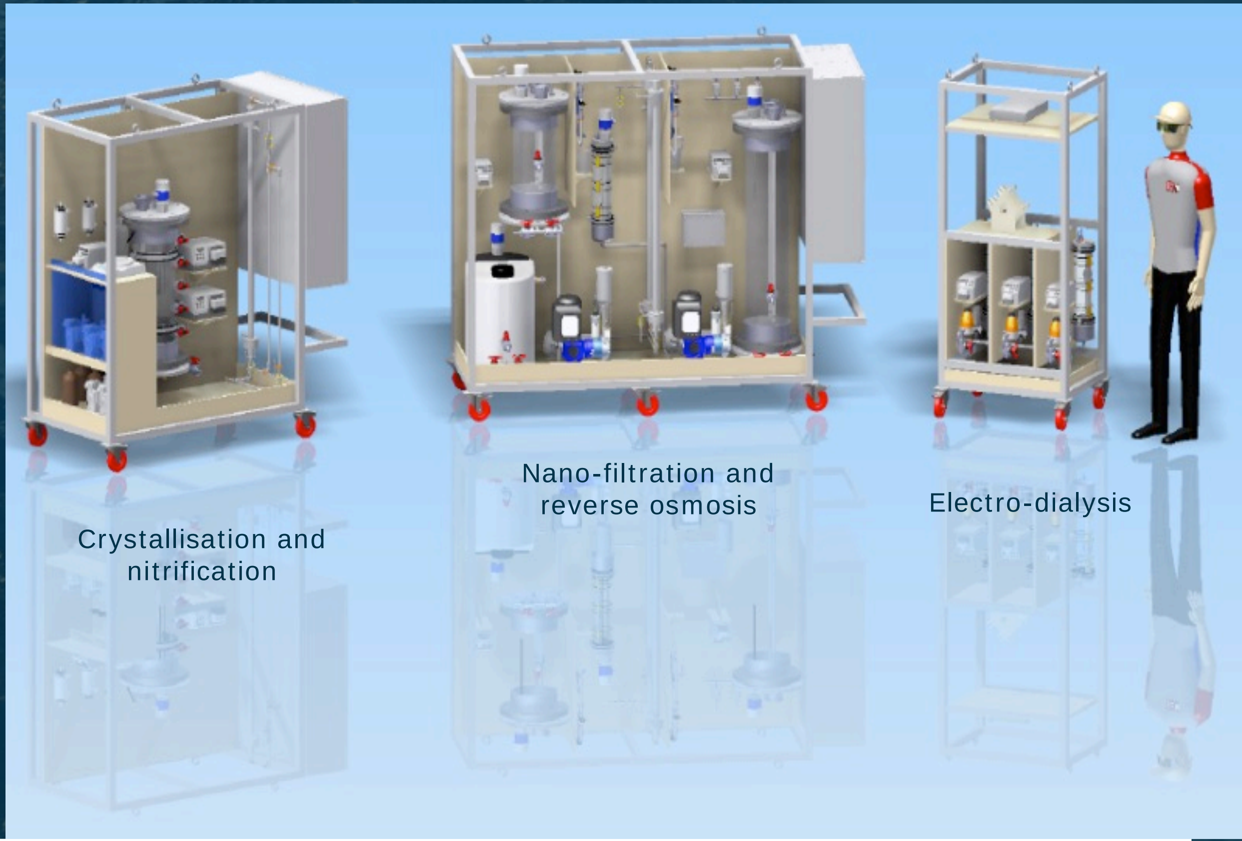
MELiSSA phase 1

Water treatment

Water represents the major mass of consumable to be uploaded and results in several streams, which need to be treated separately:

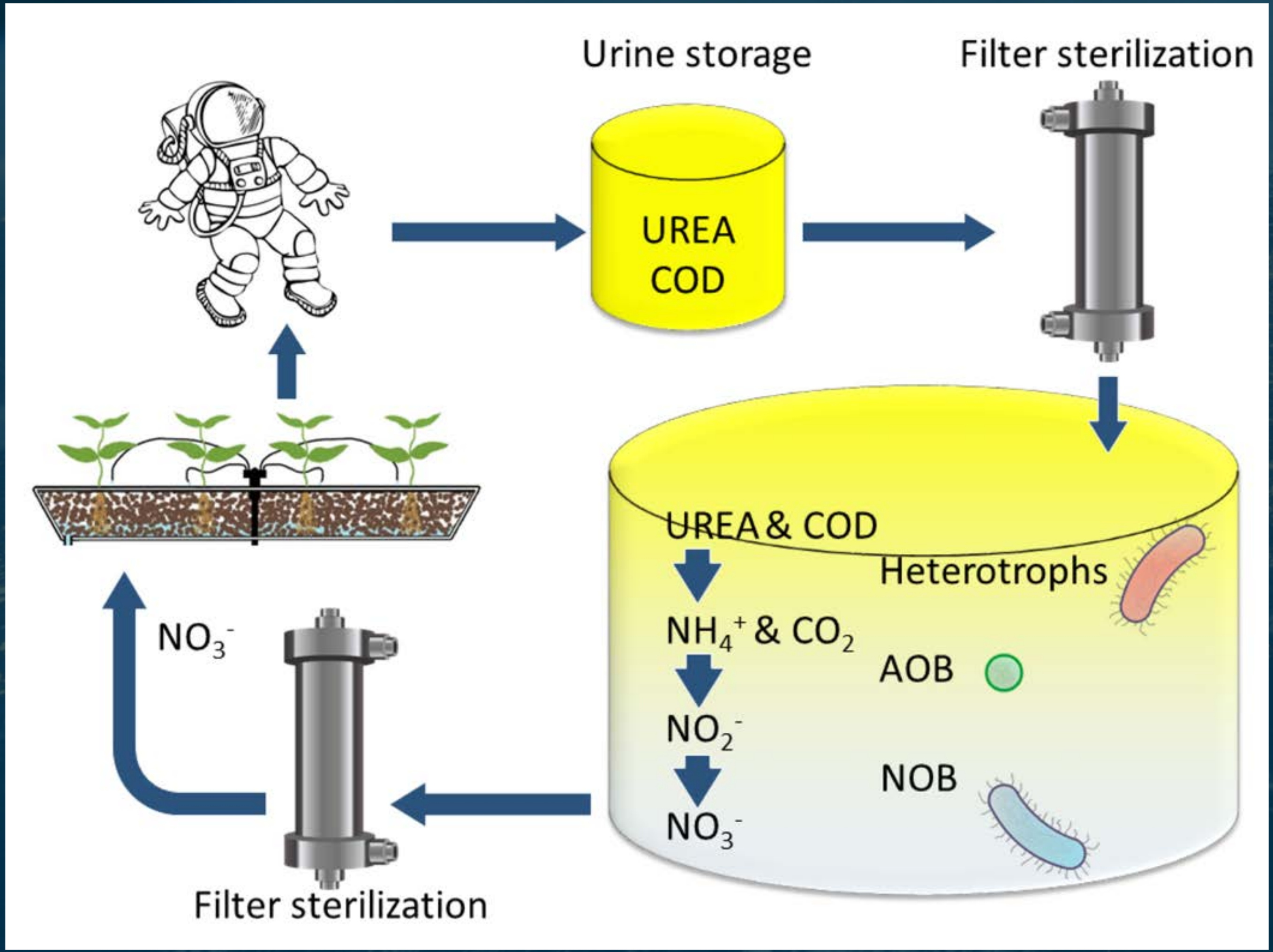
- grey water (condensate, shower,..)
- urine

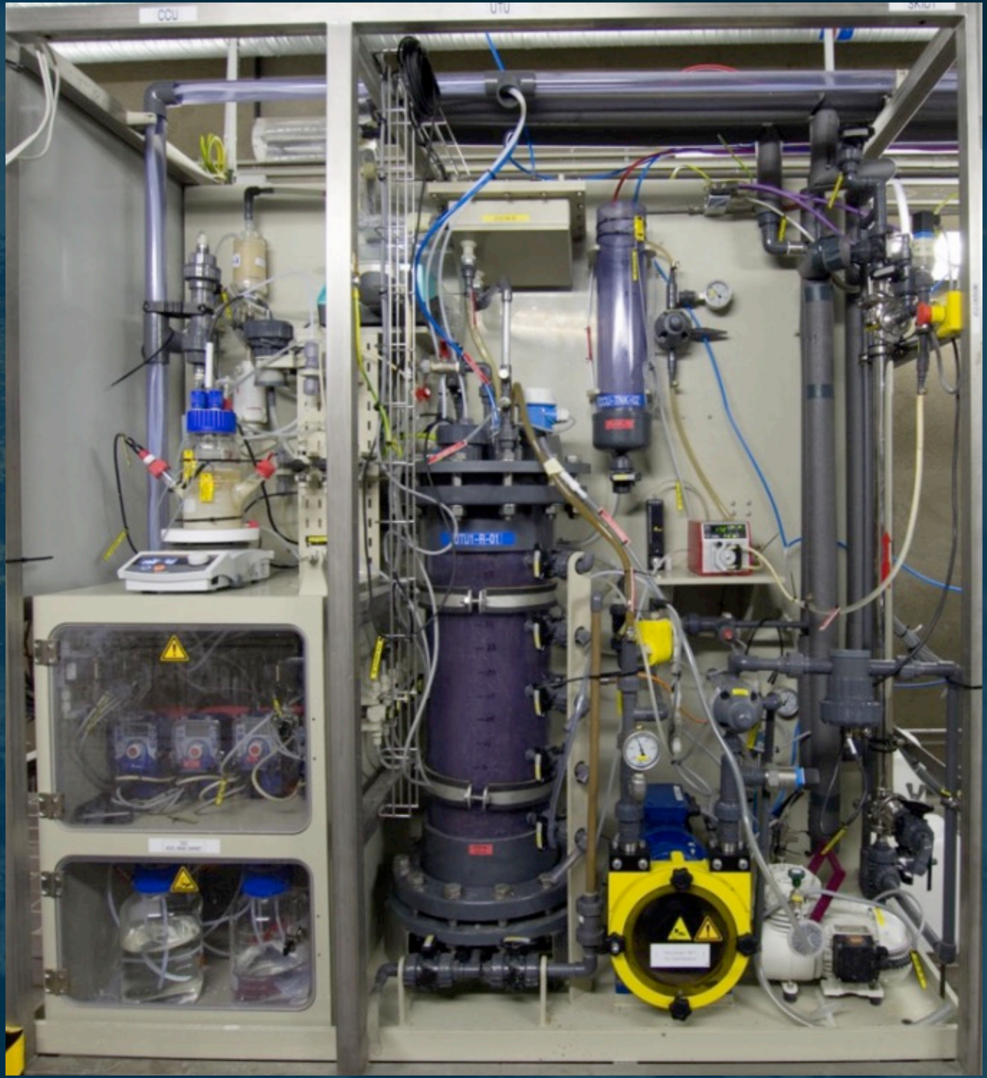
Prototype for space mission: up to 90% water recovery for treatment of urine and shower water produced by 1 person



MELiSSA phase 1

Urine conversion





MELiSSA phase 1

Waste degradation

Waste are composed of:

- crew metabolic organic matter (fecal matter)
- toilet paper
- non-edible part of crops

Complementary techniques under investigations

Liquefying bioreactor

- microbial consortium metagenomics characterisation
- functional mathematical model

Fibre degradation:

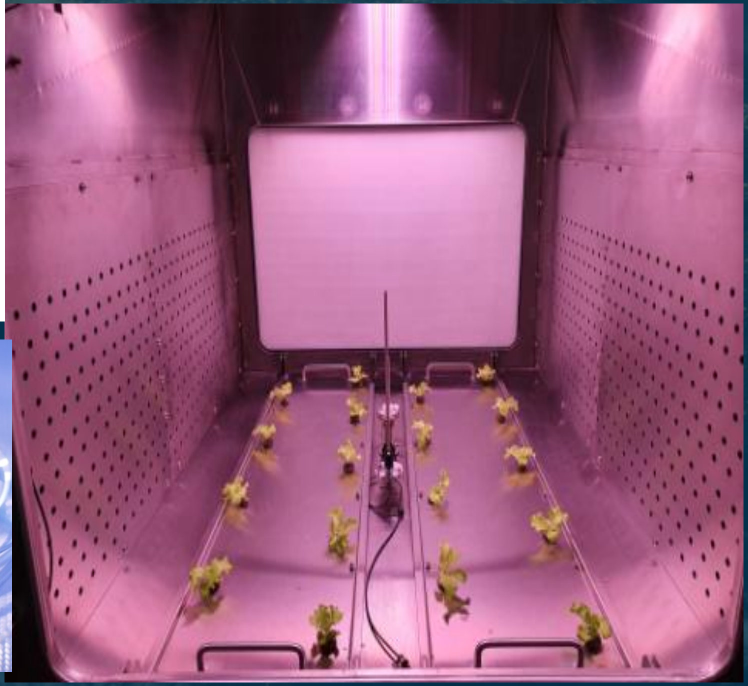
- supercritical oxidation
- bio-anode (microbiological fuel cell)

MELiSSA phase 1

Food Production and preparation

Food (i.e. edible part of higher plants) is the resulting product of the following functions:

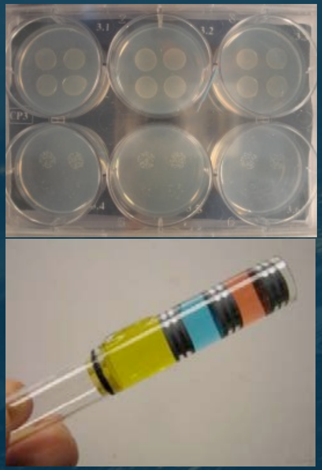
- Tests on crops
- Tests on recipes
- Tests with consumer



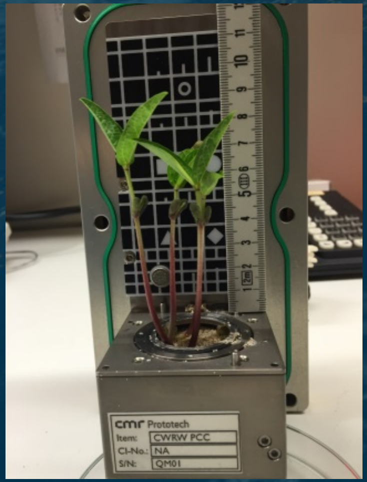
MELiSSA phase 2

From “test tubes” to bioreactor (or “small scale individual compartment”)

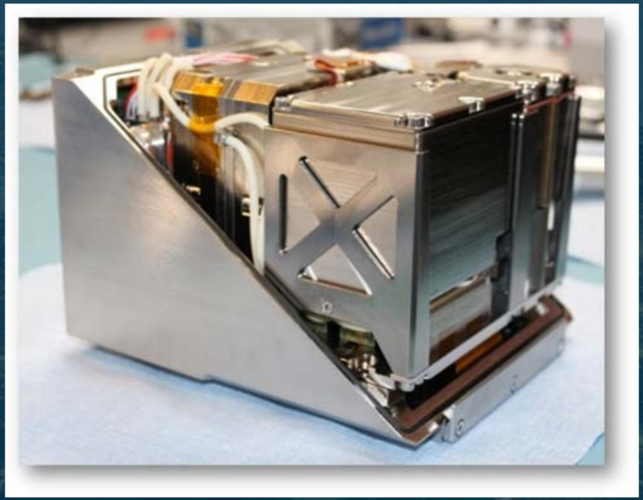
From individual compartment to connected compartments and technology demonstrators



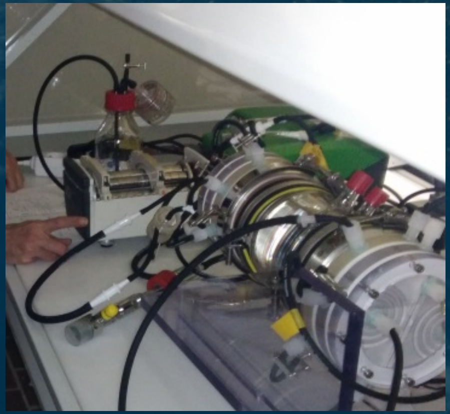
MESSAGE 1
MESSAGE 2
BASE
NITRIMEL
BISTRO



WAPS



ArtEMISS



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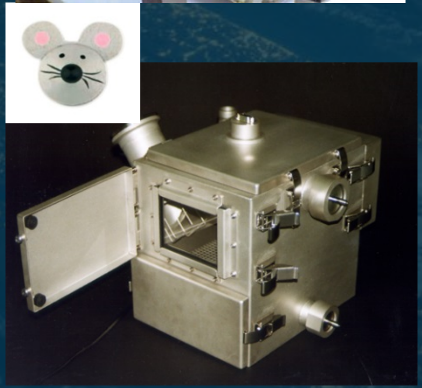


BIORAT 1

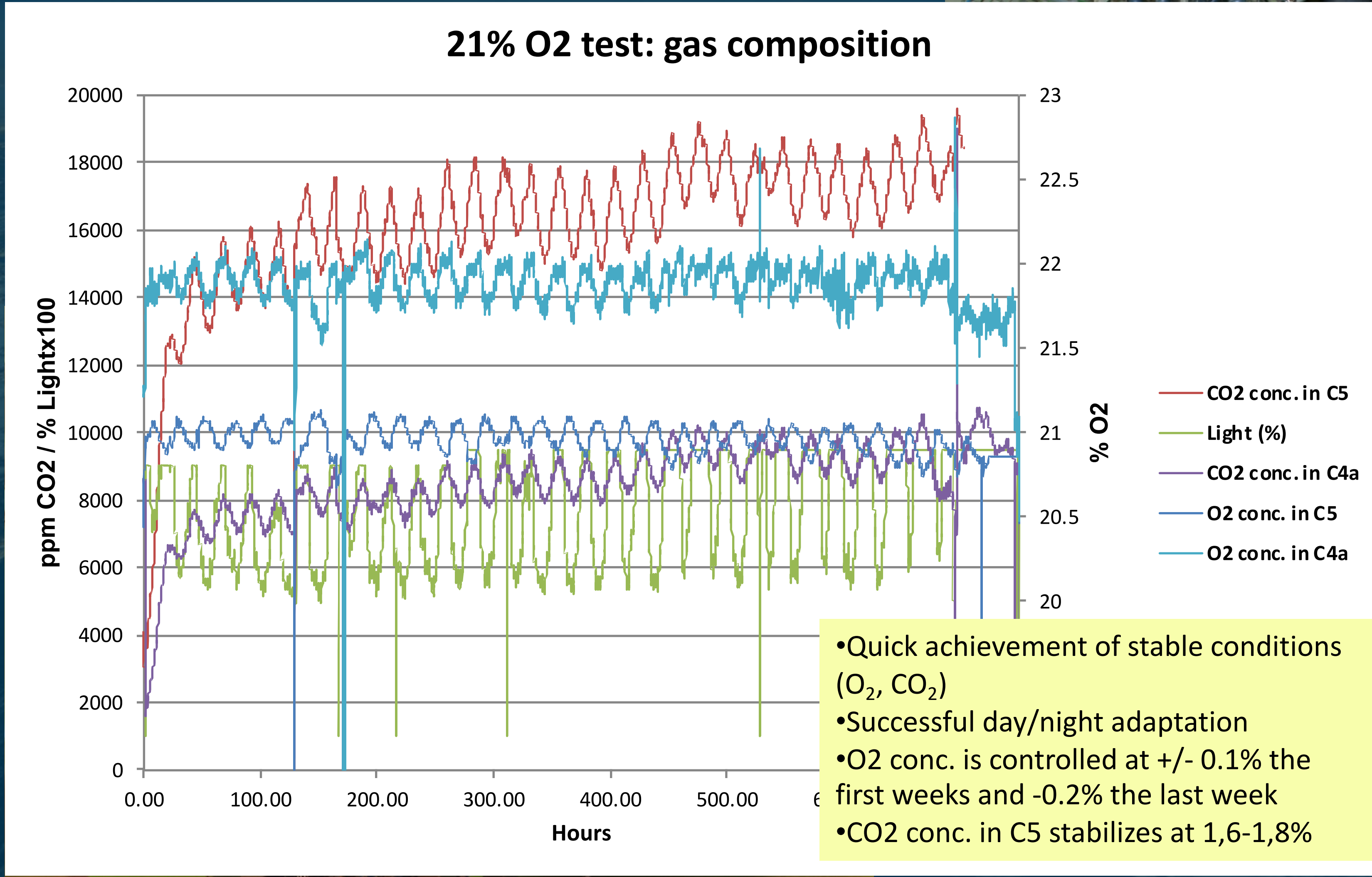
MELiSSA phase 3

MELiSSA Pilot Plant

Demonstration of air loop closure

Conversion CO2/O2

Dynamically controlled

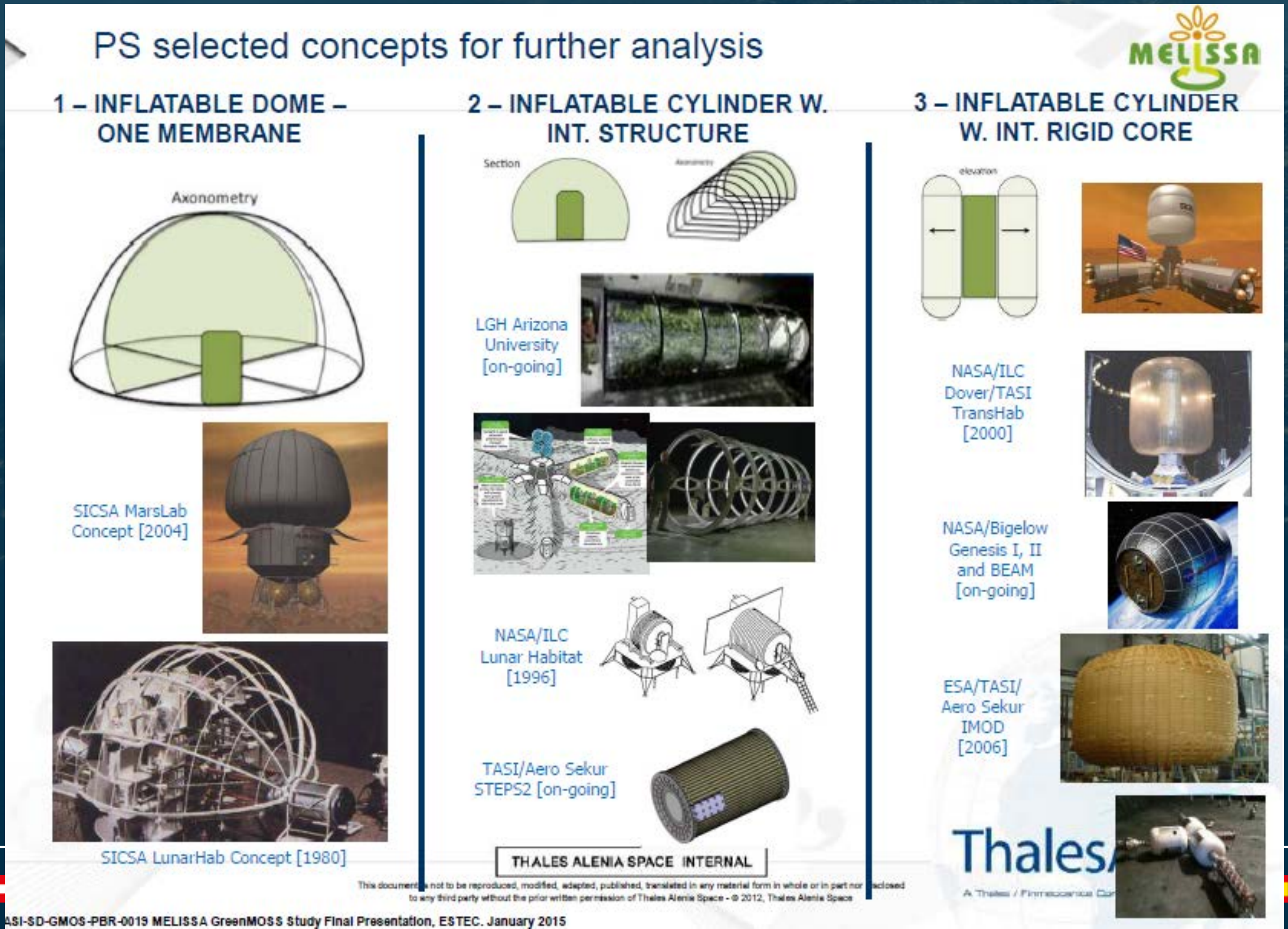


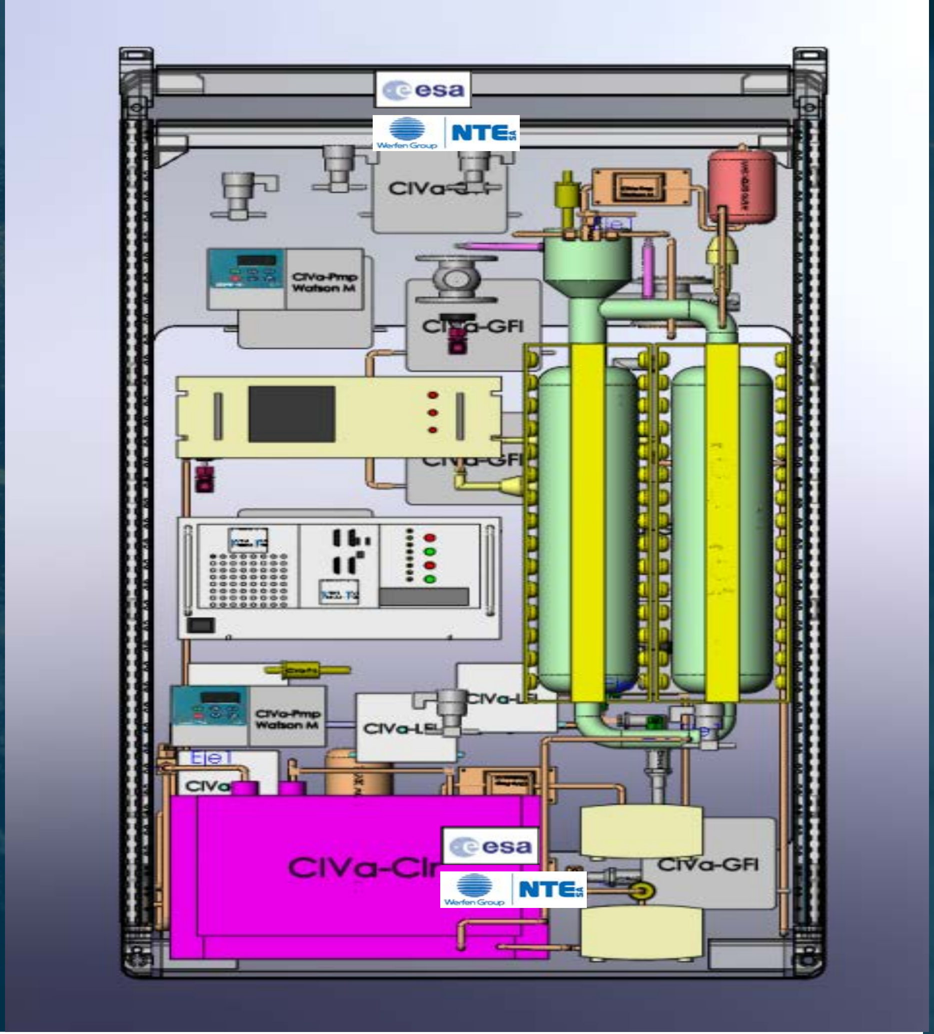
- Quick achievement of stable conditions (O_2, CO_2)
- Successful day/night adaptation
- O2 conc. is controlled at +/- 0.1% the first weeks and -0.2% the last week
- CO2 conc. in C5 stabilizes at 1,6-1,8%

MELiSSA phase 3

System studies

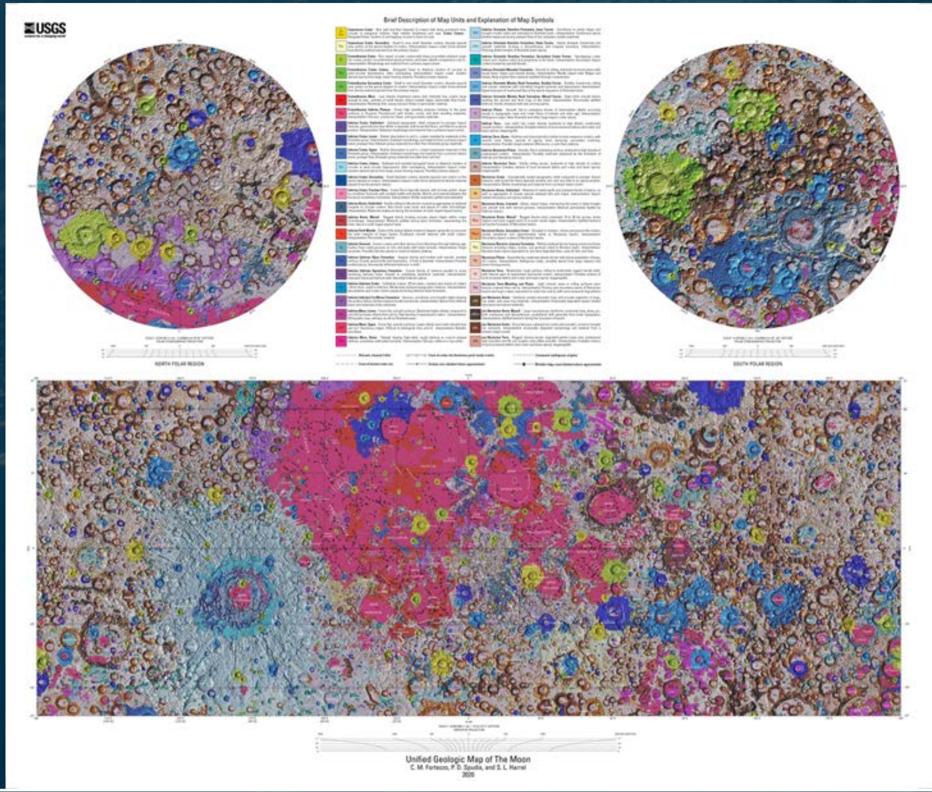
- Space Life support system preliminary sizing
- Moon greenhouse

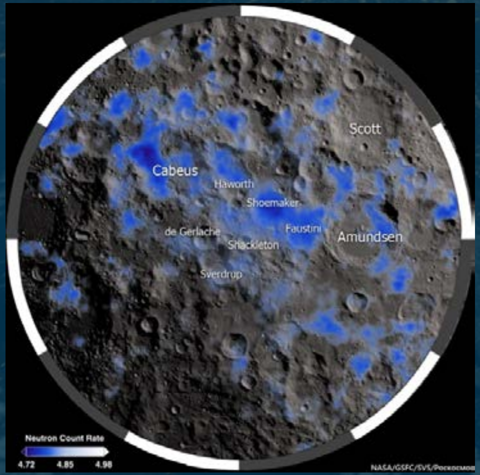


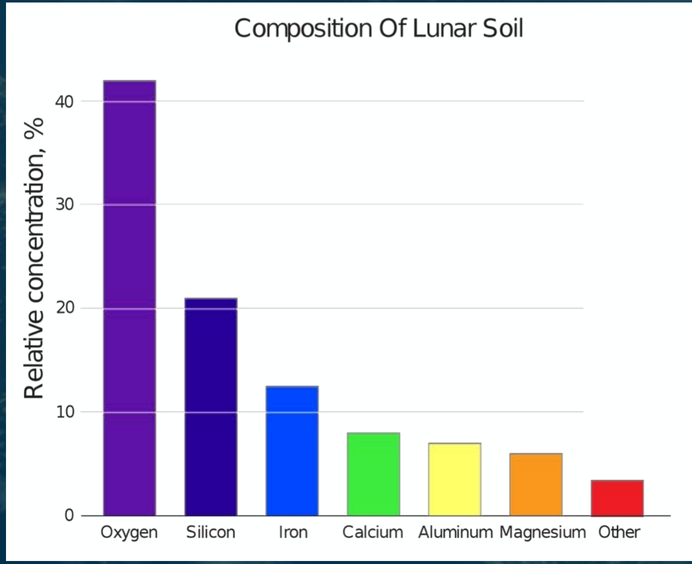


In Situ Resource Utilisation: Living off the land

- Exploration and permanent presence on planetary bodies requires best possible use of the resources
- Resources which can be used on a planetary body for sustainable presence
- Water and mineral oxygen of primary interest

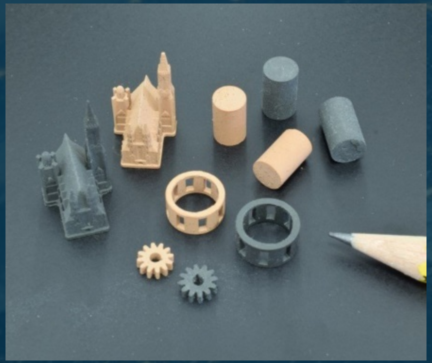




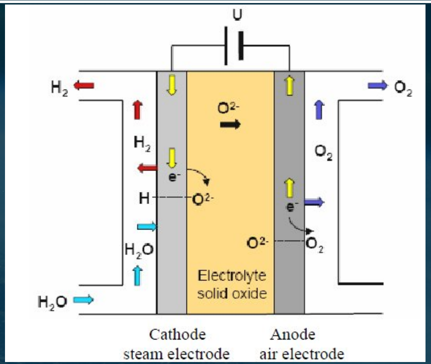


Applications of the resources

- Oxygen and hydrogen as energy source: Propulsion, habitability
- For Life Support
- As construction and as building material (regolith)



Development and qualification of processes for oxygen production



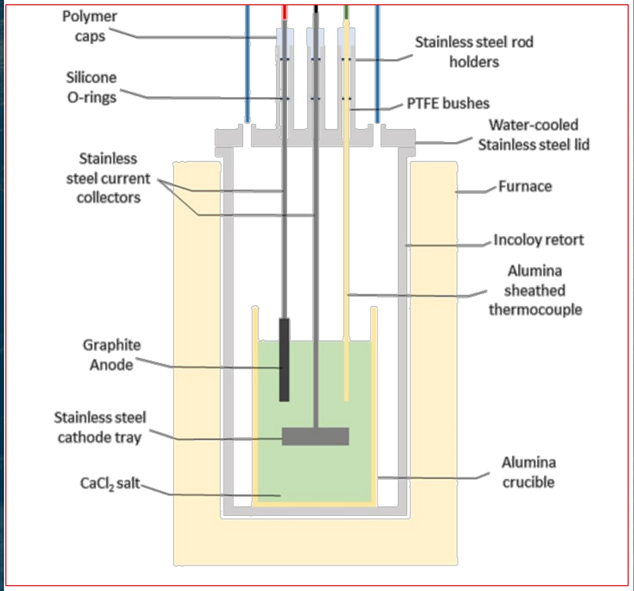
- Water Electrolysis
- **Carbothermal reduction** (1) **CH_4** + 0.5 $SiO_2(s)$ → 0.5 Si(s) + CO + **2** H_2
- **Methanation reaction**: $3H_2$+ CO → CH_4 + H_2O
- Hydrogen Reduction: $FeTiO_3$ + H_2→ H_2O + TiO_2 + Fe (s)
- Molten Salt Electrolysis:

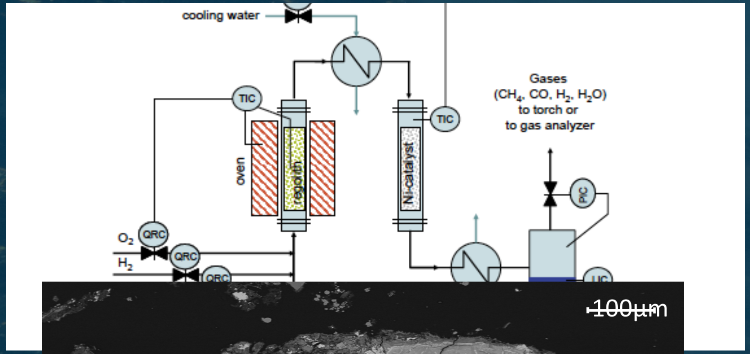
  AT THE CATHODE:

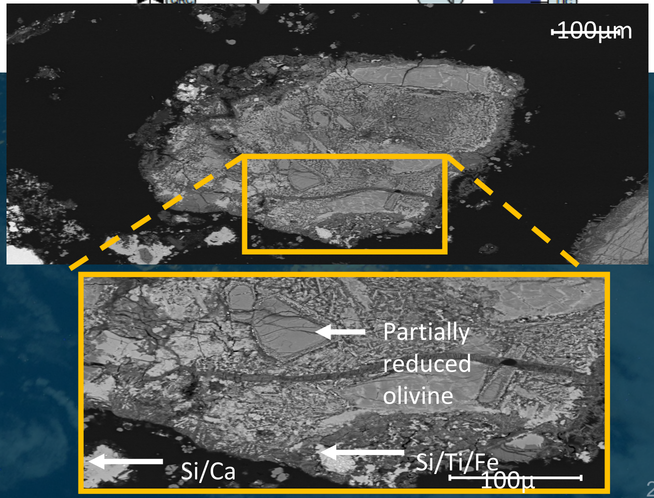
  MxOy + 2ye- → xM + yO2-

  AT THE ANODE:

  O2- → 1⁄2O2 + 2e- (inert anode)







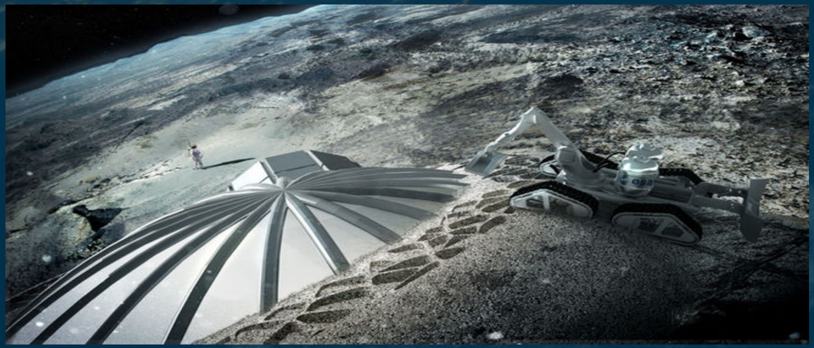
- Molten Regolith Electrolysis
- …

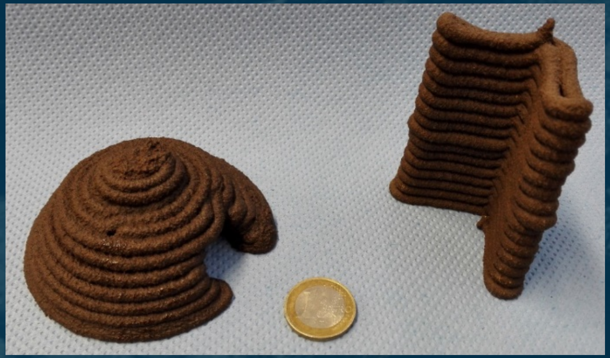
Advantages and disadvantages

- Water electrolysis: Simple and (relatively low) technological risk, Challenges is to get hold of the water (volatiles, PSR = -250C, access), provides oxygen (and hydrogen) directly
- Carbothermal reduction: Well known process, requires post processing (methanation), consumables form earth (CH_4), low yield (5-10%), energy intensive (˜900-1000C)
- Well known process, low yield (5-10%), specific to Ilmenite ($FeTiO_3$), energy intensive
- Molten Salt Electrolysis (FFC Cambridge process): High Yield, (˜70% oxygen), but technological risk and as well energy intensive (900C)

Current efforts in ESA/Europe

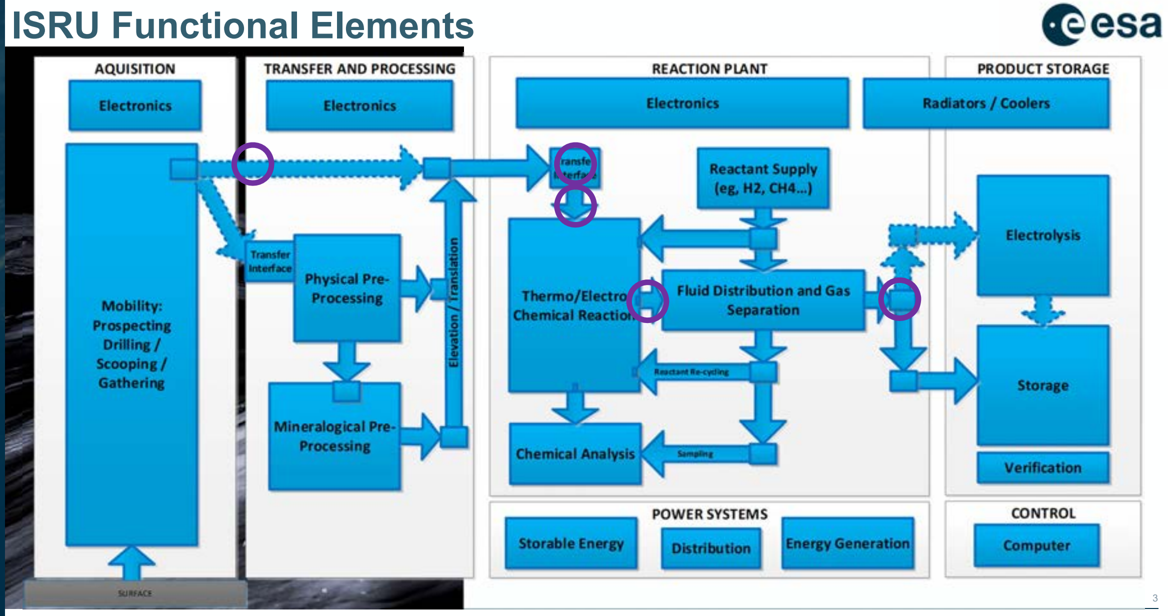
- Work on Ground Demonstrator for carbothermal/hydrogen reduction processes
- Work on industry side and internal R&D on molten salt electrolysis: Increase energy efficiency, corrosion, adaptation, materials to space environment…)
- Energy storage aspects (reversible solid oxide electrolysis)
- Phase A/B of an ISRU demonstrator mission to be scheduled for 2028
- Establishment of the European Resource Utilisation Centre, ESRIC (Luxemburg), bundling R&D and user applications (commercial, institutional) for resource utilization in space
- Work on additive and in-space manufacturing: Building materials, habitats, advanced engineering materials
- Supporting technology developments (dust resilience, efficient heating, reactor technology…)

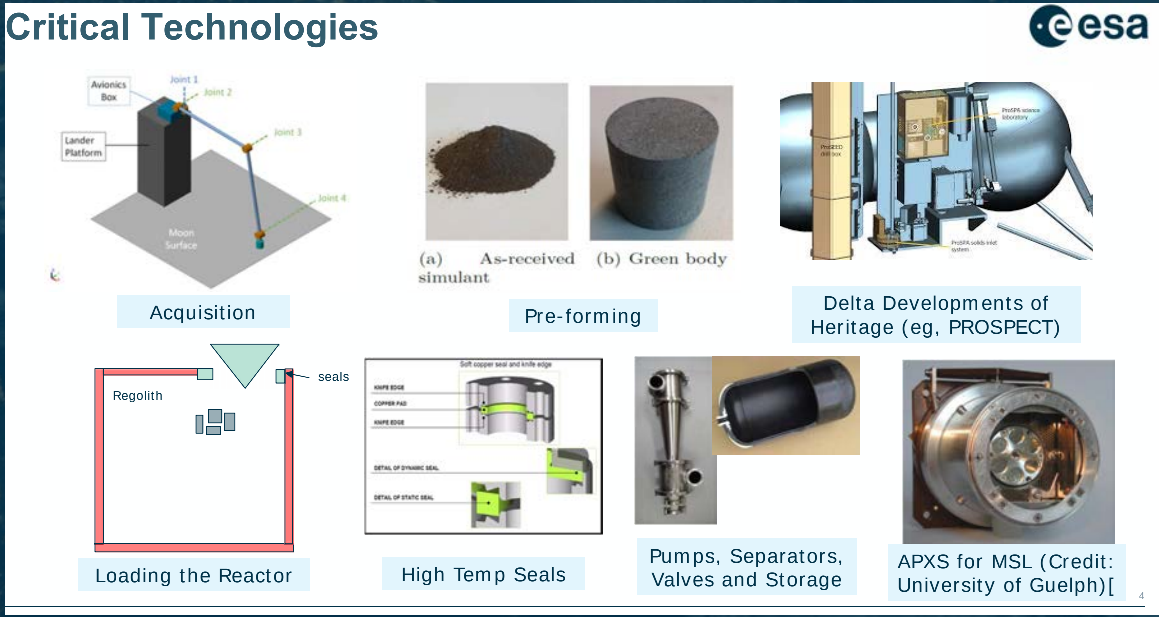




ISRU DM study

- Objective is to produce oxygen on the surface of the moon and demonstrate the ISRU functional elements
- Phase A study finalized
- Phase B1 study to start in 2021: Challenge and then down selection of one concept
- Payload shall weigh no more than 80kg
- Launch with commercial or institutional lander
- Technology maturation necessary





Open Call on space resources: www.ideas.esa.int

More information on MELiSSA: www.melissafoundation.org

Thank you!

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