MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

Spaceship FR

CREATING A CIRCULAR FUTURE

RÉPUBLIQUE FRANÇAISE
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# SPACESHIP FR & MELiSSA: HARMONIZED ROADMAPS FOR REGENERATIVE LIFE SUPPORT SYSTEMS

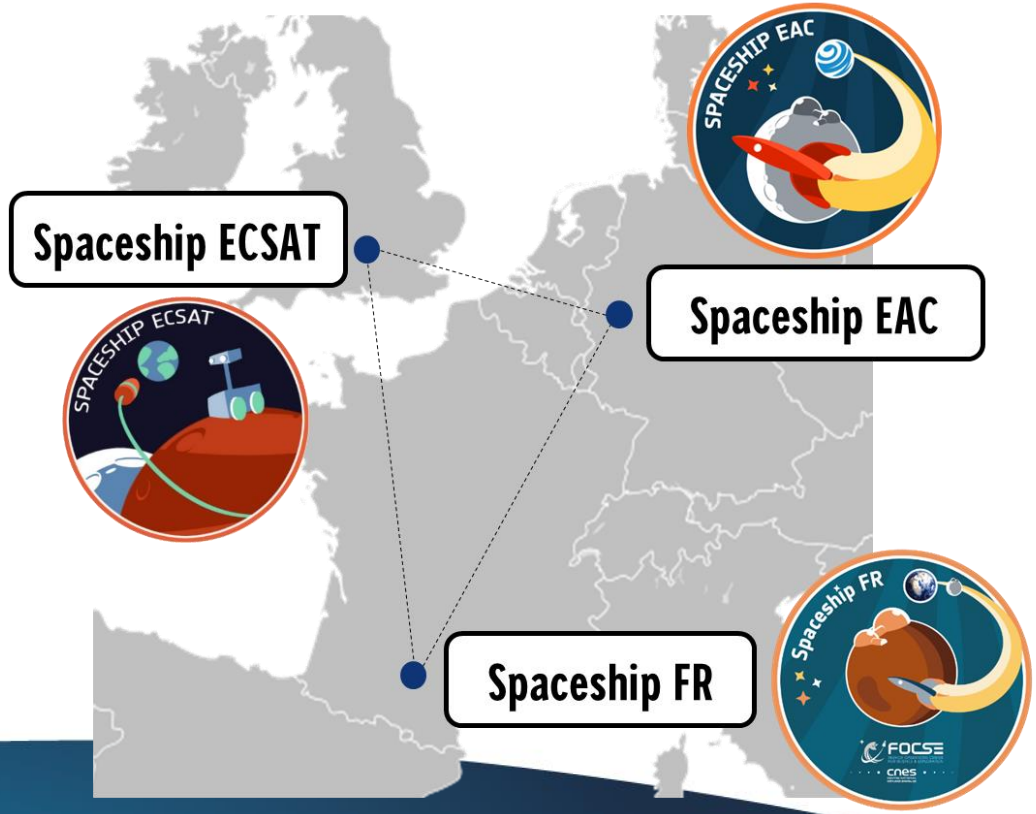
## Session SYSTEM STUDIES 2/3 – 2022/10/09

cnes

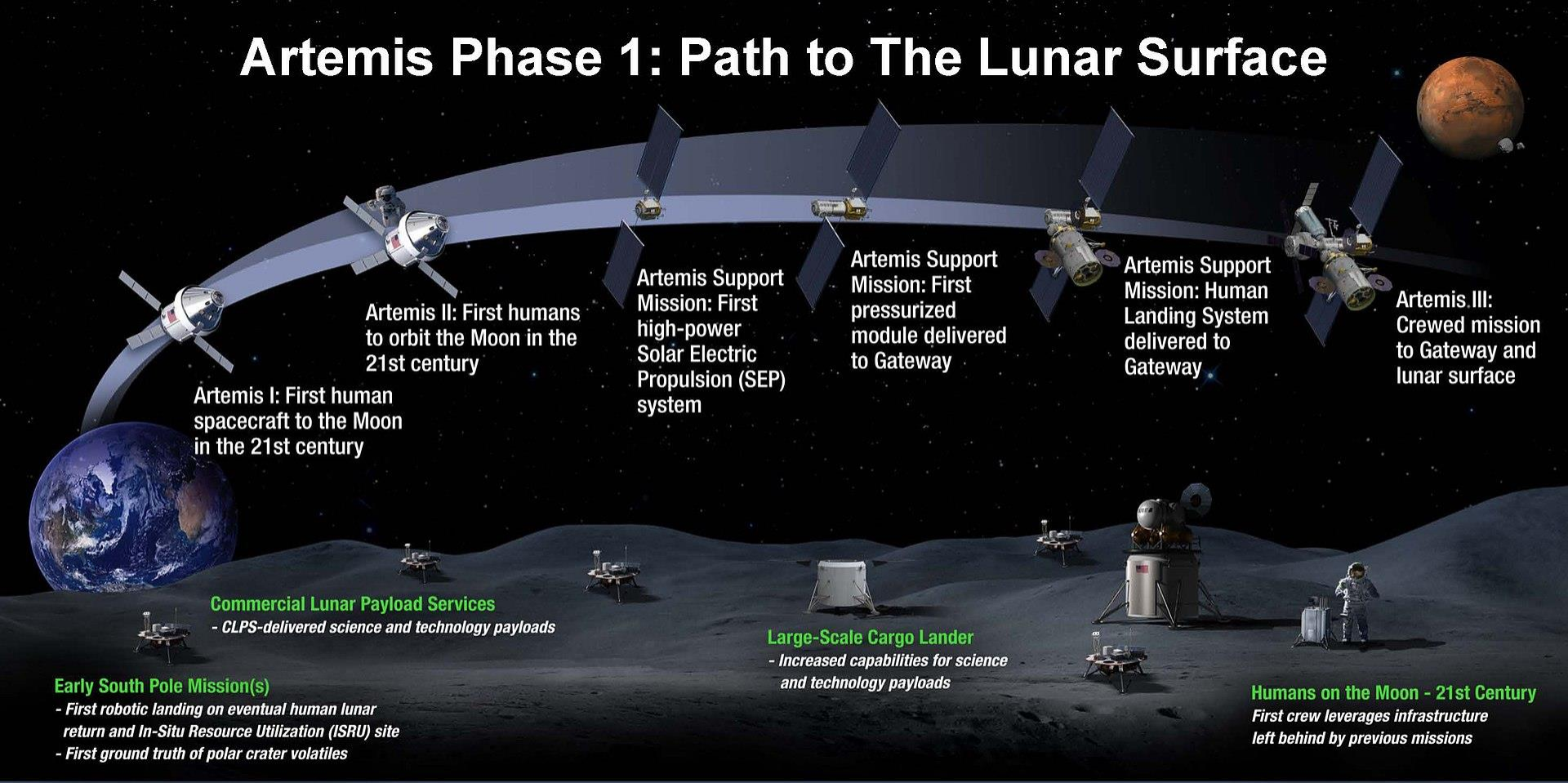
Context
Objectives
Results
Conclusion and perspectives with MELiSSA

Context
Objectives
Results
Conclusion and perspectives with MELiSSA

# SPACESHIP FR – Context – Spaceships netw

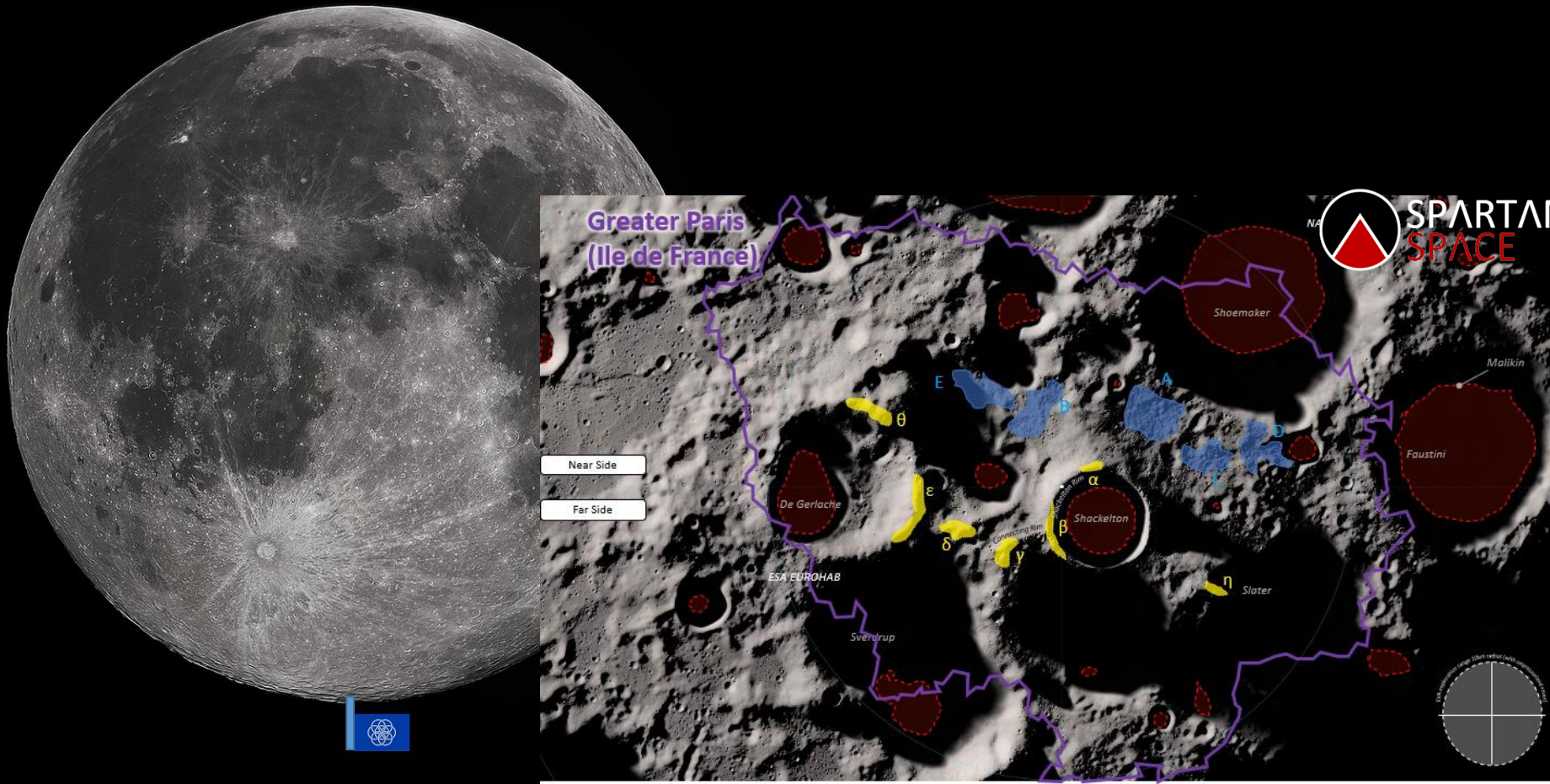



# Artemis Phase 1: Path to The Lunar Surface




**LUNAR SOUTH POLE TARGET SITE**

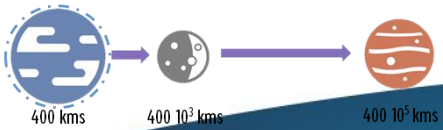
2020 2024

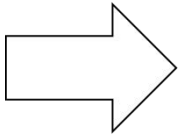

Greater Paris
(Ile de France)
SPARTAN
SPACE
Near Side
Far Side
Shoemaker
Malikin
Faustini
De Gerlache
Shackelton
ESA EUROHAB
Sverdrup
Slater
A
B
D
E
F
α
β
γ
δ
ε
η
θ
Possible Human Landing Sites
(Near-side & slope 0° - 10° &
less 10km from pole)
High Illumination Sites
(above 60% over lunar month)
Permanently Shadowed
Regions
0
10
20 km
(Pole)
Animated Chart: NASA Visualization Studio; link: https://svs.gsfc.nasa.gov/4770
Author: Peter WEISS, p.weiss@spartan-space.com

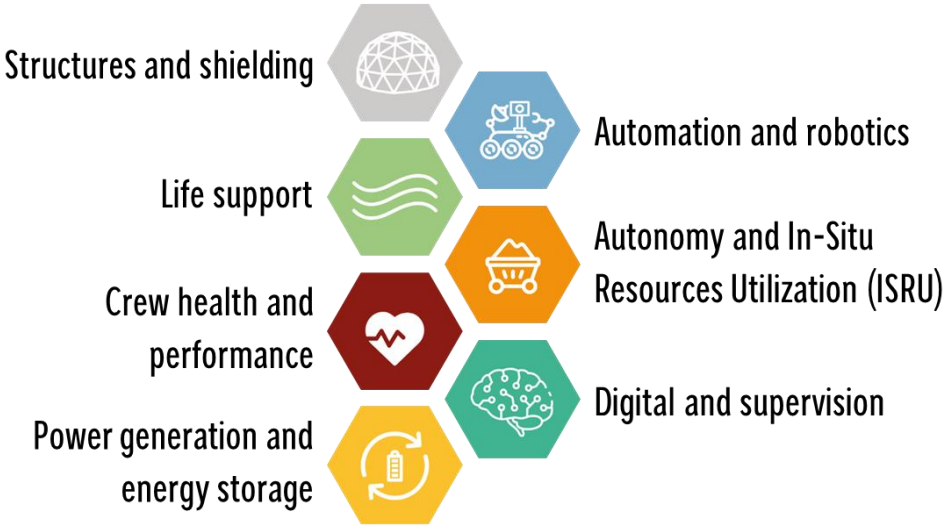
# MELISSA SPACESHIP FR – Context – Scope for Exploration



**GLOBAL EXPLORATION ROADMAP**

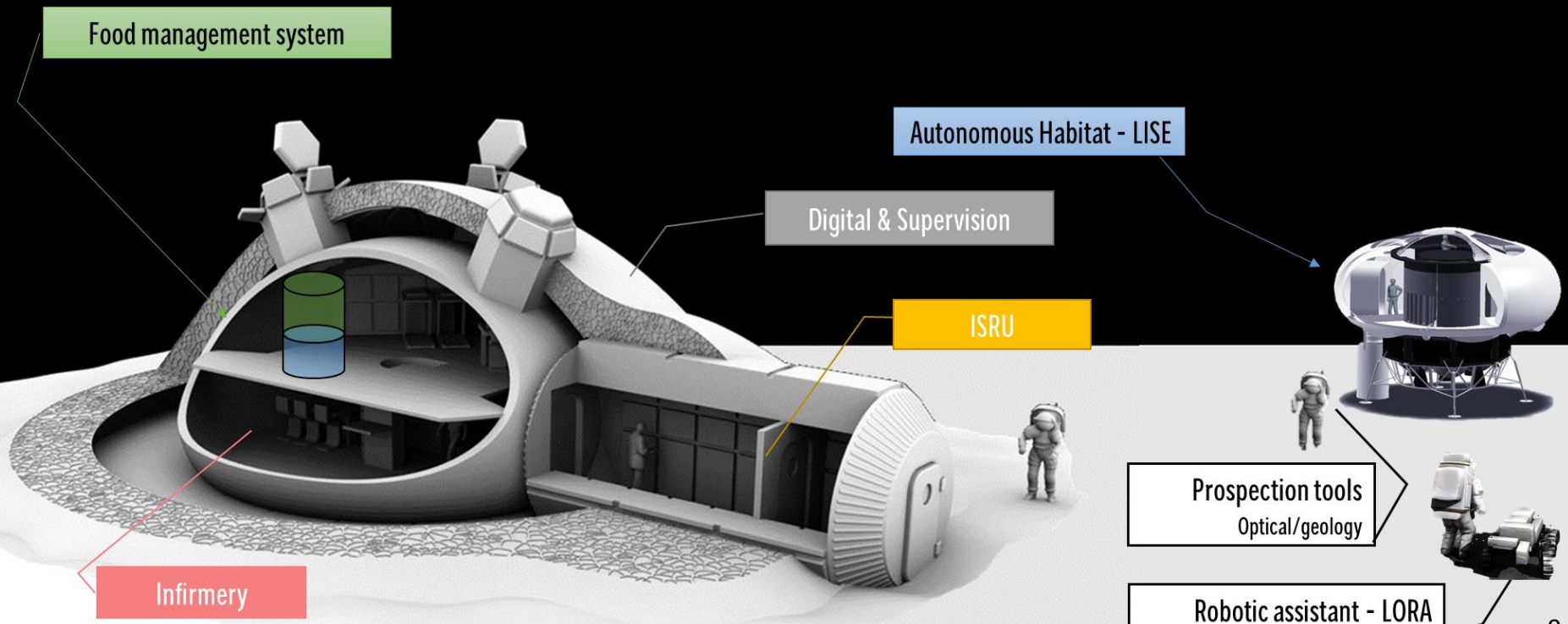




# Key Drivers

## Subsystems in the international outpost



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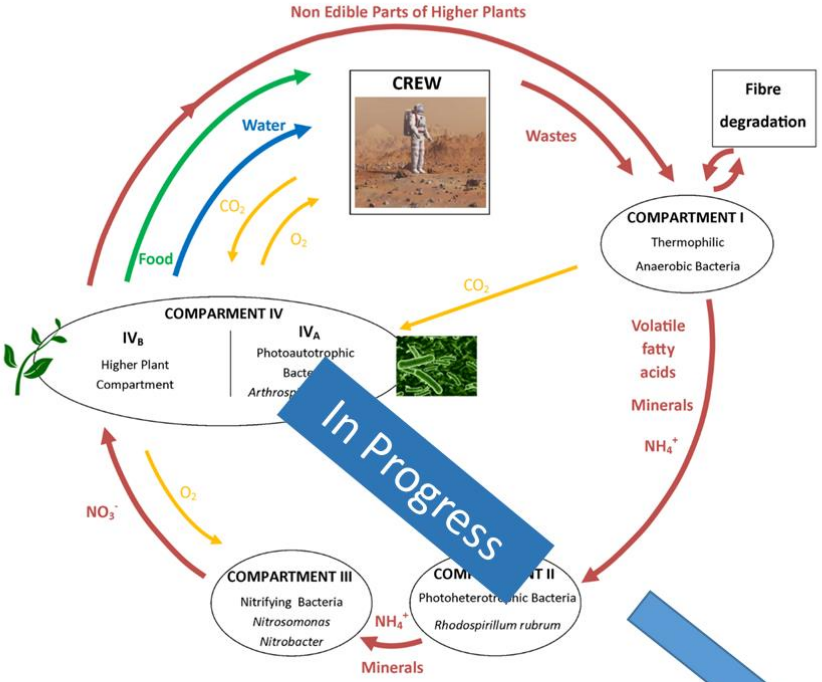
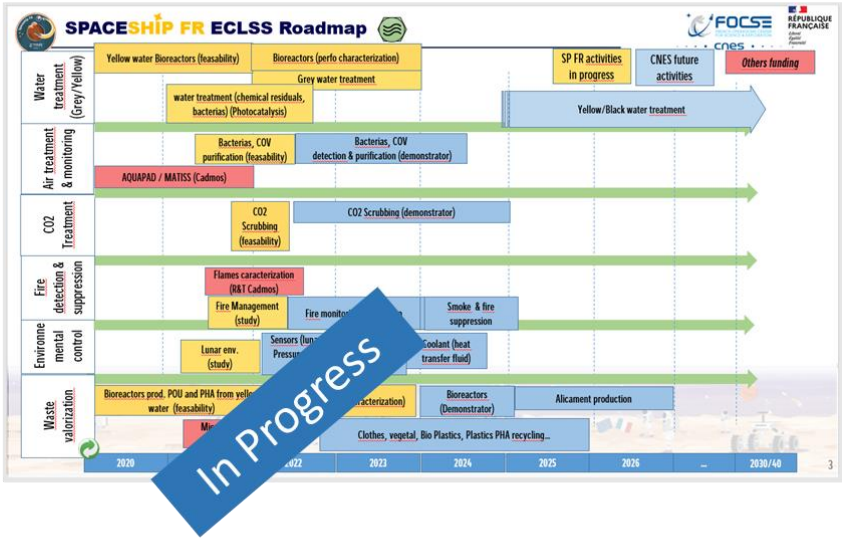
# MELISSA SPACESHIP FR – Objectives




Discussions, comparisons, identification of the complementary technological bricks

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# MELiSSA SPACESHIP FR – Roadmaps Comparison

| TOPICS | MELiSSA | SPACESHIP FR |
|---|---|---|
| Air Recycling & CO2 revalorization | ✓ | ✓ |
| Food Production | ✓ | ✓ |
| Grey Water Recycling | | ✓ |
| Yellow Water Recycling | ✓ | ✓ |
| Black Water Recycling | ✓ | ✓ |
| Waste Recycling | ✓ | ✓ |
| Biomaterials | ✓ | ✓ |
| Process modelling, Simulation & Control | | ✓ |
| Life Support Architecture for Future Missions | ✓ | |
| Fire Management | ✓ | |
| Flight Experiments | | ✓ |

# MELiSSA SPACESHIP FR – Topics selection

| TOPICS | MELiSSA | SPACESHIP FR |
|---|---|---|
| Air Recycling & CO2 revalorization | ✓ | ✓ |
| Food Production | ✓ | ✓ |
| Grey Water Recycling | | ✓ |
| Yellow Water Recycling | ✓ | ✓ |
| Black Water Recycling | ✓ | ✓ |
| Waste Recycling | ✓ | ✓ |
| Biomaterials | ✓ | ✓ |
| Process modelling, Simulation & Control | | ✓ |
| Life Support Architecture for Future Missions | ✓ | |
| Fire Management | ✓ | |
| Flight Experiments | | ✓ |

# MELiSSA SPACESHIP FR – Air Recycling and CO2 Valorisation

## MELiSSA

| Objective |
| --- |
| CO2 removal and reprocessing + O2 generation |
| **Technology** |
| CIVa: Micro-algae photobioreactor (*Limnospira indica*) |
| **Space TRL** |
| TRL4 |

| Objective |
| --- |
| CO2 removal and reprocessing + O2 generation |
| **Technology** |
| CIVb: Higher plant growth chamber |
| **Space TRL** |
| TRL3 |

## SpaceShip FR

| Objective |
| --- |
| CO2 trapping |
| **Technology** |
| Cryo-liquefaction |
| **Space TRL** |
| TRL2 |

| Objective |
| --- |
| CO2 trapping |
| **Technology** |
| Solid fibre |
| **Space TRL** |
| TRL3 |

# MELISSA SPACESHIP FR – Air Recycling and CO2 Valorisation

**2022 Activities: Study, assessment and test of solid fibers for H20 capture**

- State of the art of adsorbent technologies for H2O then CO2
- Comparison of adsorbent
- Update of the test bench
- Tests of different configurations / materials => excellent kinetics with fibers and no dust

**Future Activities: Development of a functional breadboard to treat and valorise H2O and CO2**

- Evaluation of the suitable shape for adsorbent
- Design canisters (including the right proportion of adsorbent) for the requirement
- Develop and test a ground functional breadboard (test under vacuum)

# MELiSSA SPACESHIP FR – Food Production 1/2

## MELiSSA

| Objective |
| --- |
| Protein production for human crew consumption |
| **Technology** |
| CIVa: Edible biomass cultivation in micro-algae photobioreactor (*Limnospira indica*) |
| **Space TRL** |
| TRL4 |

| Objective |
| --- |
| Higher plants production for human crew consumption |
| **Technology** |
| CIVb: Higher plant cultivation in growth chamber |
| **Space TRL** |
| TRL3 |

## SpaceShip FR

| Objective |
| --- |
| Protein prod. for human crew and aquaculture consumption |
| **Technology** |
| AstroPOU module: Edible biomass cultivation via heterotrophic fermentation in bioreactor (*Cupriavidus necator*) |
| **Space TRL** |
| TRL3 |

| Objective |
| --- |
| Higher plants production for human crew consumption |
| **Technology** |
| Biomebox©: Higher plant cultivation in growth chamber |
| **Space TRL** |
| TRL4 |

# MELiSSA SPACESHIP FR – Food Production 2/2

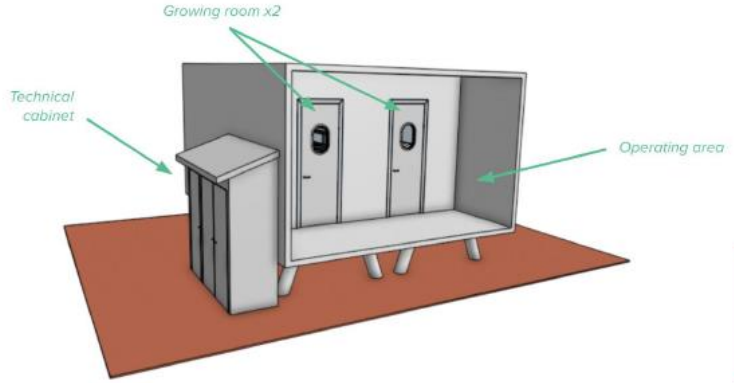
## MELiSSA

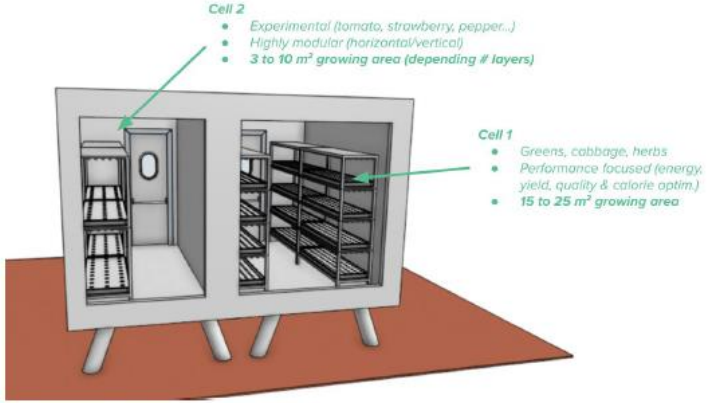
## SpaceShip FR

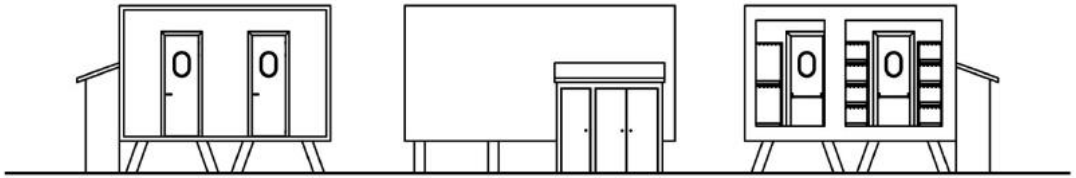
| Objective |
| --- |
| Food production for human crew consumption |
| **Technology** |
| Fish farming module |
| **Space TRL** |
|  |

# MELISSA SPACESHIP FR – Food Production perspectives

Toulouse Spaceship demonstrator : a first step towards spatialization of indoor farming technologies



On a 30 m² footprint, this module can produce up to 10 kg per day of fresh fruits & vegetables for a budget lower than 2 000 €/m² of crop space

# MELiSSA SPACESHIP FR – Food Production perspectives

**Next started studies and prototypes in 2022:**

- Root vegetable production performance tests
- Mushrooms production prototype => new incomes for nutrition
- Mushrooms nursery prototype => grow mycelium

**Next potential studies & Perspectives:**

- Study the use of PHA substrate for germination
- Study the use of pressure variation to produce interesting molecules (pharmaceutic interest)
- Develop a digital twin => anticipate failure modes
- Define a model-plant referential and typical culture protocols for crew alimentation => realization of cycles of tests to characterize them and build a database
- Study the integration of water treatment system => recycle nutritive solutions
- Study the effects of the air flux on the plant growth => optimize air circulation and thermal exchanges

# MELiSSA SPACESHIP FR – Yellow water recycling

## MELiSSA

| Objective |
| --- |
| **Transformation of urine in proper substrate for higher plants and micro-algae cultivation** |
| **Technology** |
| CIII: Heterotrophic nitrifying bioreactor (*Nitrosomonas europaea*, *Nitrobacter winogradskyi*, *Comamonas testosteroni*) |
| **Space TRL** |
| TRL2 |

| Objective |
| --- |
| **Nitrogen gas recovery from urine to compensate for gas leakages in crewed habitat** |
| **Technology** |
| Partial Nitritation/Anammox + Membrane Aerated Biofilm Reactor |
| **Space TRL** |
| TRL2 |

## SpaceShip FR

| Objective |
| --- |
| **Urine recycling for bacterial biomass cultivation** |
| **Technology** |
| AstroPOU module: Heterotrophic fermentation in bioreactor (*Cupriavidus necator*) |
| **Space TRL** |
| TRL3 |

| Objective |
| --- |
| **Sanitation of drinking water removing persistent chemical and bacteriological polutant** |
| **Technology** |
| Oxydo-reduction without additives thanks to photocatalyst & UV excitation |
| **Space TRL** |
| TRL3 |

# MELiSSA SPACESHIP FR – Black water recycling

## MELiSSA

| Objective |
| --- |
| Black water and human faeces recycling |
| **Technology** |
| CI: Thermophilic (55°C) anaerobic bacterial degradation. Inoculum coming from DRANCO (DRy ANaerobic COmposting) process. |
| **Space TRL** |
| TRL2 |

## SpaceShip FR

| Objective |
| --- |
| Black water and human faeces recycling |
| **Technology** |
| Anaerobic digester module |
| **Space TRL** |
| TRL1 |

# MELiSSA SPACESHIP FR – Waste Recycling 1/2

## MELiSSA

| Objective |
| --- |
| Inedible organic waste recycling |
| **Technology** |
| CI: Thermophilic (55°C) anaerobic bacterial degradation. Inoculum coming from DRANCO (DRy ANaerobic COmposting) process. |
| **Space TRL** |
| TRL4 |

| Objective |
| --- |
| Bioplastics recycling |
| **Technology** |
| Bio-degradation in controlled conditions and compatible with MELiSSA processes |
| **Space TRL** |
| TRL1 |

## SpaceShip FR

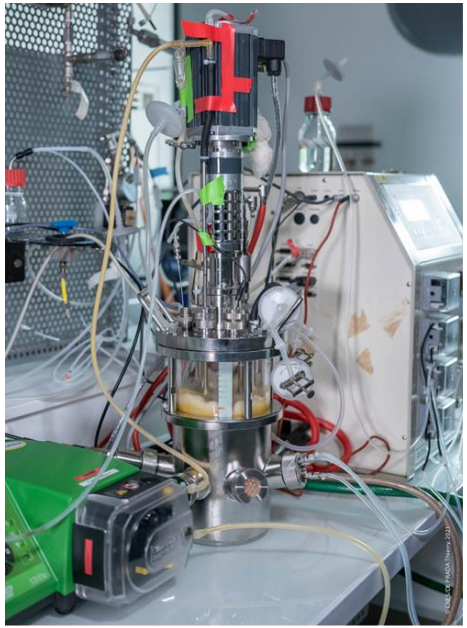
| Objective |
| --- |
| Volatile Fatty Acids recycling |
| **Technology** |
| AstroPOU module: Heterotrophic fermentation (*Cupriavidus necator*) |
| **Space TRL** |
| TRL3 |

| Objective |
| --- |
| Bioplastics recycling |
| **Technology** |
| PHA recycling for reuse in 3D-printer |
| **Space TRL** |
| TRL1 |

# MELiSSA SPACESHIP FR – Waste Recycling 2/2

| MELiSSA | SpaceShip FR |
| --- | --- |
| **Objective** | |
| Inorganic waste recycling | |
| **Technology** | |
| Compaction | |
| **Space TRL** | |
|   | |

# MELISSA SPACESHIP FR – Recycling perspectives



See Presentation "Assessing the Recycling Potential of Cupriavidus necator for Space Travel: Production of SCPs and PHAs from Organic Waste."
By Pierre JORIS - TBI
Session Biomaterial 2/2 2022/11/10
At 13h30 Room 1

## In 2022

**Intensification and consolidation of the concept to reach TRL 4 :**

- Process optimization in terms of reactor monitoring and inlet composition
- Evaluation of the product quality
- Evaluating the possibility to reduce or suppress Oxygen supply

## Perspectives 2024

- Oxygen supply : Evaluation of the production of PHAs under limited or lack of oxygen. Impact on the quality of the polymers.
- Coupled production of unicellular proteins and nutraceuticals in C. necator: feasibility study, implementation, evaluation
- Scaling-up the AstroPOU process : Approaching real case situation ; Demonstrator in the Spaceship Lab.

# MELiSSA SPACESHIP FR – Biomaterials

| MELiSSA |
| --- |
| **Objective** |
| **Packaging production** |
| **Technology** |
| Non-edible biomass 3D printing |
| **Space TRL** |
| TRL2 |

| SpaceShip FR |
| --- |
| **Objective** |
| **Bioplastic production** |
| **Technology** |
| AstroPOU module: Heterotrophic fermentation (*Cupriavidus necator*) + Bioplastic separator |
| **Space TRL** |
| TRL2 |

See Presentation "Assessing the integration of a bioreactor producing SCPs and PHAs from organic waste into global environmental systems."
By Etienne PERRIN - CNES
Session Biomaterial 1/2 2022/11/09
At 08h50 Room 1

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# MELiSSA SPACESHIP FR – Harmonized Roadmaps

| TOPICS | MELiSSA | SPACESHIP FR |
|---|---|---|
| Air Recycling & CO2 revalorization | ✓ | ✓ |
| Food Production | ✓ | ✓ |
| Grey Water Recycling | | ✓ |
| Yellow Water Recycling | ✓ | ✓ |
| Black Water Recycling | ✓ | ✓ |
| Waste Recycling | ✓ | ✓ |
| Biomaterials | ✓ | ✓ |
| Process modelling, Simulation & Control | | ✓ |
| Life Support Architecture for Future Missions | ✓ | |
| Fire Management | ✓ | |
| Flight Experiments | | ✓ |

# MELiSSA SPACESHIP FR – Collaboration perspectives

| TOPICS | |
|---|---|
| Grey Water Recycling | Investigate **cloth washing** technologies |
| Yellow Water Recycling | Piggy-back on upcoming **CNES bed rest studies** to look at correlation between diet, microbiota and urine composition |
| | **Test MELiSSA recipe** of synthetic urine composition on **AstroPOU** module |
| Black Water Recycling | **Study on microbiota** to better understand organic waste composition |
| | Study the feasibility of **how Volatile Fatty Acids produced in MELiSSA** CI could be fed **into AstroPOU** fermentation module |
| Food Preparation | Investigate **biomass** transformation **into recipe** |
| Packaging | Investigate synergies on **biodegradable packaging** (CNES EcoPack Flight Technology Demonstrator) and **freshness packaging** (CNES Freshness Packaging Technology Demonstrator) |
| Radiations | **PhD on radioprotection** and DNA/RNA reconstruction |

# MELISSA SPACESHIP FR – Acknowedgements

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European Space Agency

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# THANK YOU.

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