MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR **FUTURE**

A ROADMAP FOR FUTURE SYSTEM STUDIES

Lessons Learned in VARSITY

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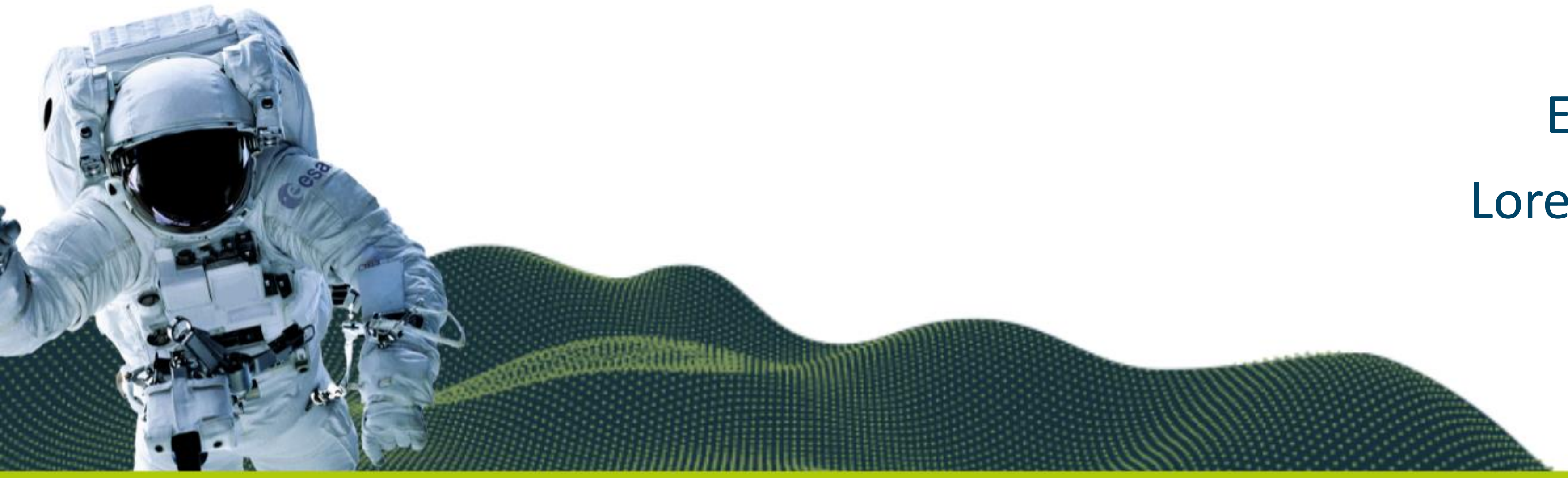

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Outline

Context

- VARSITY project – Motivation and objectives

VARSITY – Lessons learned

- Mathematical models of MELiSSA compartments
  - *Model Readiness Level (MRL)*
- System simulation of the MELiSSA loop
  - *State Vector, Sizing, System Readiness Level (SRL)*

Conclusion

- Insights for future system studies

VARSITY project

Motivation and objectives

VARSITY project – Motivation and objectives

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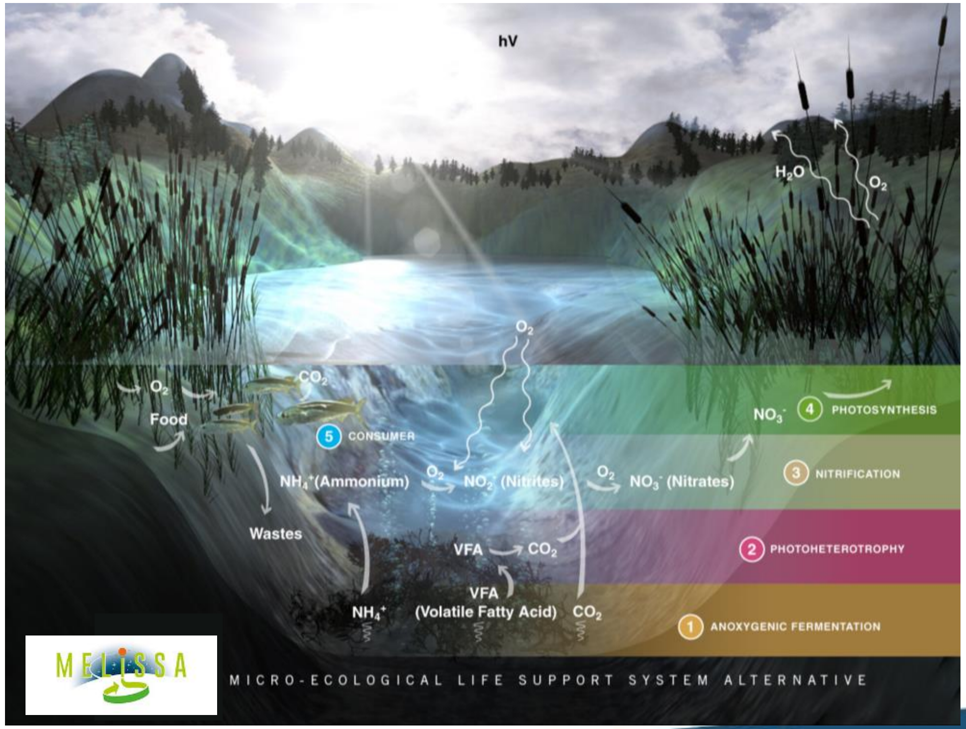
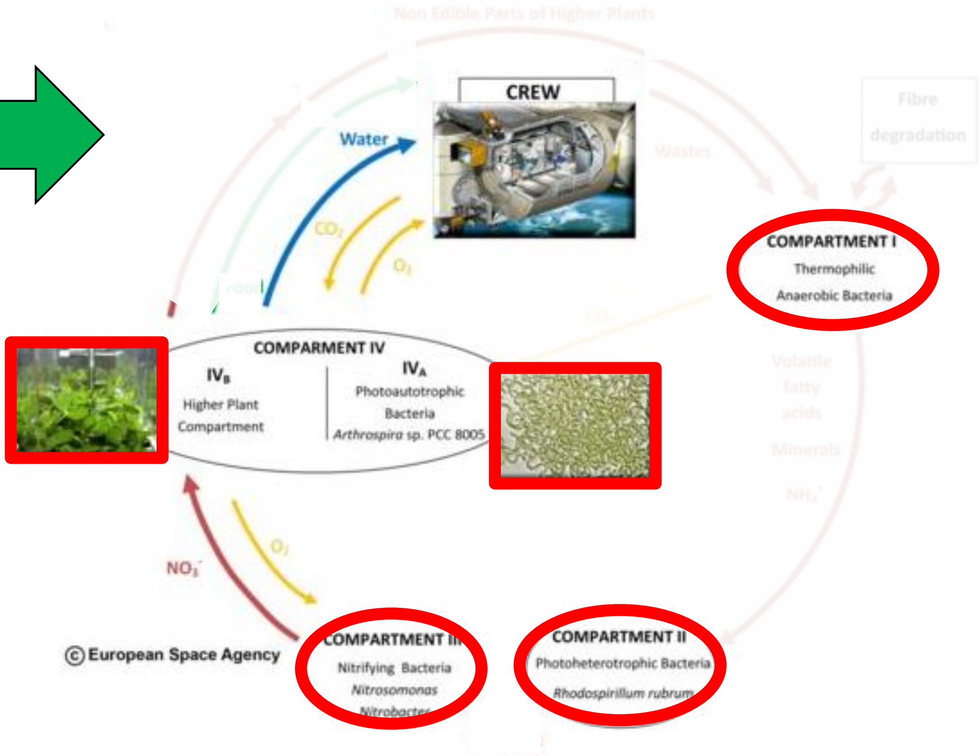
Extract from Varsity SOW

"In the framework of the MELiSSA project, ***system studies are crucial at all levels of developments*** *…*
However, mechanistic models as well as predictive control have been demonstrated mainly at sub-units *and within limited range of process behavior "*





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VARSITY project – Motivation and objectives

Extract from Varsity SOW

*"In the framework of the MELiSSA project, **system studies are crucial at all levels of developments** … **However, mechanistic models as well as predictive control have been demonstrated mainly at sub-units** and within limited range of process behavior "*

Control loop strategy

Mathematical models

System simulation

FOCUS OF TODAY'S PRESENTATION

Main VARSITY objective

Focus on the Global Network

Industrial deployment of ALISSE

ALISSE V2 development

ALISSE criteria for a Mars Transit Mission

VARSITY – Lessons learned #1

Mathematical models

- MRL - Assessment

VARSITY – Lesson Learned #1
Mathematical models

Model Readiness Level

Table 5: Current status of models for the MELiSSA compartments: MRL Scale

System	MRL	Perimeter
Bioreactor C1	2-4	Mass balance only
Bioreactor C2	2-4	Mass balance only
Bioreactor C3 - autotrophic	7	Dynamic-fixed bed-autotrophic Nitrification
Bioreactor C3 - Urea	3-4	Dynamic-fixed bed-heterotrophic Nitrification
Bioreactor C4a	8-9	Dynamic
Bioreactor C4b	3-4	Mass Balance only
Bioreactor C4b	4 ?	Gaz phase (? Liq? Solid?)
Crew – C5	3-4	Mass balance only
Crew – C5	5-7	For gas dynamic (CO_2/O_2) of rats

More details in UCA's presentation (L. Poughon)

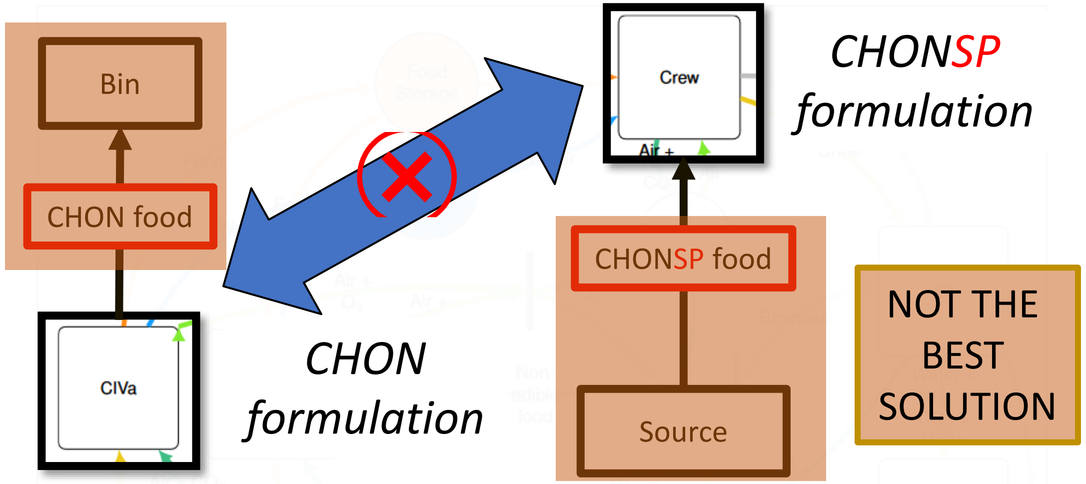
VARSITY – Lessons learned #2

System simulation

- State Vector (SV)
- Sizing issue
- System Readiness Level (SRL)

VARSITY – Lesson Learned #2
System simulation

Melissa loop – Functional model



	Physical State Vector	Component State Vector
C4a PHOTOSIM M - Hydrodynamic PBR Model 21.1	Reactor design: • Flat / cylindrical / lightning • Gas and liquid phase volumes. • Illuminated volume fraction Input flows: • Gas and liquid flow rate. • Gas O_2 & CO_2 partial pressures. Liquid composition. Light energy flux. kLa. Temperature. Pressure. pH.	CO_2 (L/G) O_2 (L/G) Ammonia (L/G) Urea (L) Nitrate (L) H_2SO_4 (L) H_3PO_4 (L) C4a L. Indica biomass (S)

✓ APPROVED BY ESA

M… tion

First definition of the State Vector for MELiSSA (TN 142.1)

Issue #1: models compatibility

- E.g. CHON / CHONSP formulation (stoichiometric model)

C=carbon
H=hydrogen
O=oxygen
N=nitrogen

S=sulfur
P=phosphorus

CIVa stoichiometry

$$reagents \rightarrow [\mathbf{CHON}]\mathbf{food} + other\ products$$

CV stoichiometry

$$[\mathbf{CHONSP}]\mathbf{food} + other\ reagents \downarrow products$$

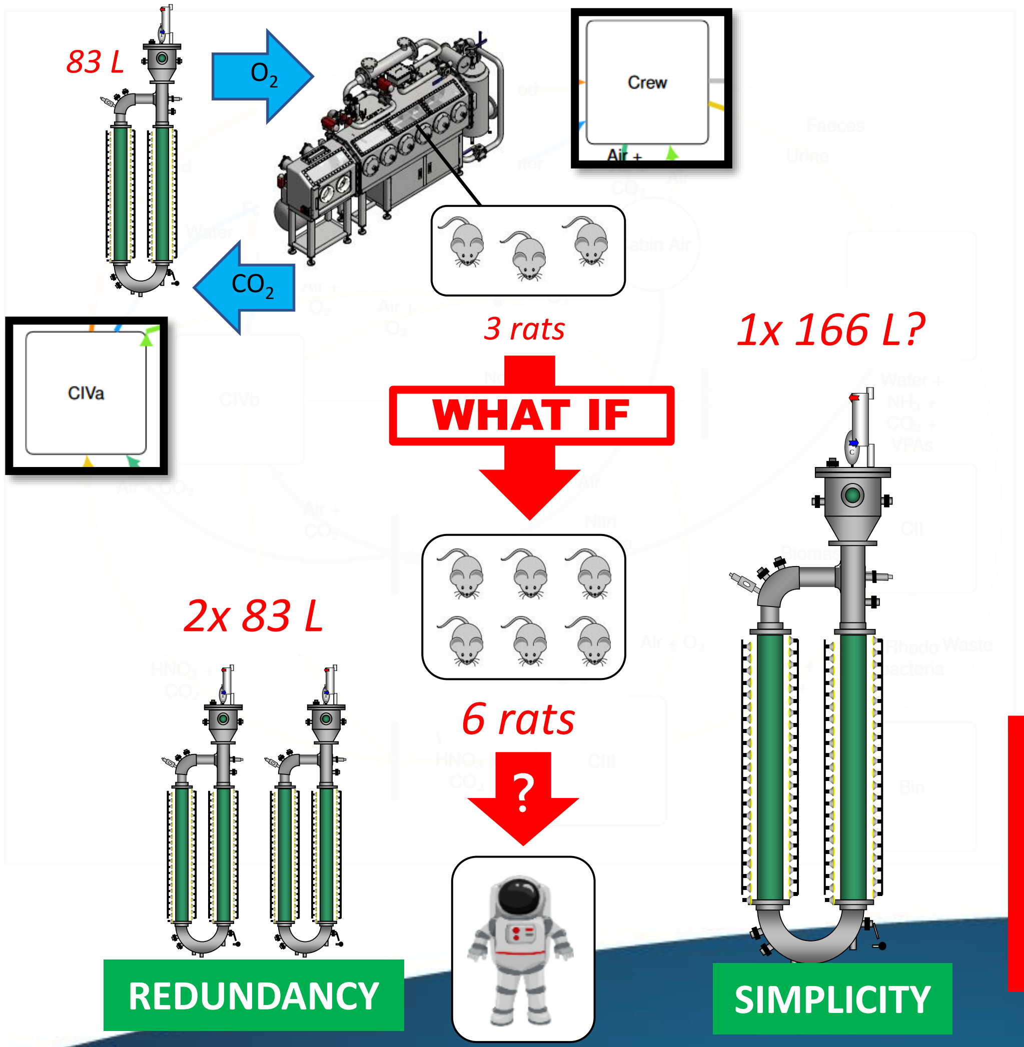
Interface issues between compartments

State Vector (SV) definition to avoid incompatibilities

BETTER SOLUTION

VARSITY – Lesson Learned #2
System simulation

Melissa loop – Functional model



Issue #2: sizing

- Current models of MELiSSA compartments and connections (distributors, pipes, …) do not consider volumes (mass balance models) or are validated for fixed volumes (e.g. C4a)

System simulation scenarios are limited

How to take into account system sizing?

Mechanistic models of MELiSSA compartments need sizing

Which is the best strategy for system design?

First introduction of System Readiness Level (SRL) in TN142.1

Conclusions

Insights for future system studies

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Conclusions

Mathematical models

FUTURE SYSTEM STUDIES

Model Readiness Level (MRL)

- Non-homogeneity of knowledge and modelling of compartments

▸▸ Plan activities to close the gaps ▸▸ MRL as reference to plan this effort

System simulations

State Vector (SV)

- First definition approved by ESA

▸▸ SV to be agreed between partners ▸▸ Models to be updated accordingly

Sizing

- Current simulation scenarios are limited

▸▸ Mechanistic models of compartments need sizing

System Readiness Level (SRL)

- First definition in VARSITY TN142.1

▸▸ Discuss with ESA an engineering strategy for compartments connections (e.g., favor redundancy over simplicity)

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THANK YOU.

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