Conceptual design of a life support system for a Mars Transit Vehicle

Project ISAE-Supaero – ESA

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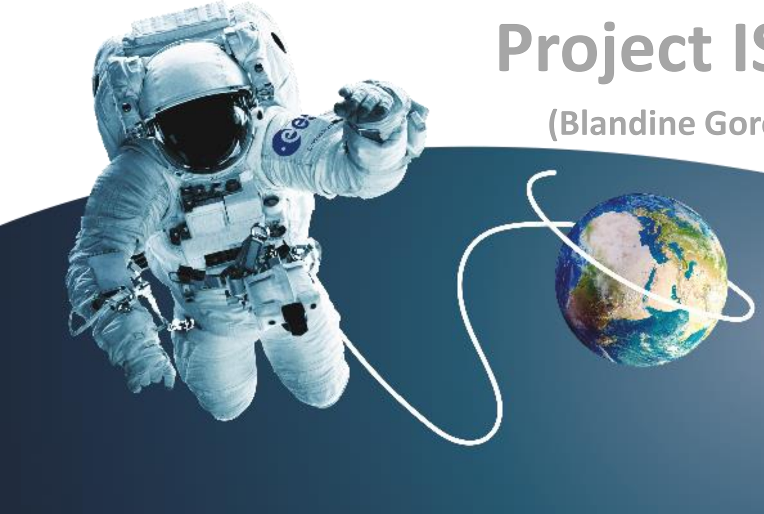

I- Context

I- Context Analysis (1)

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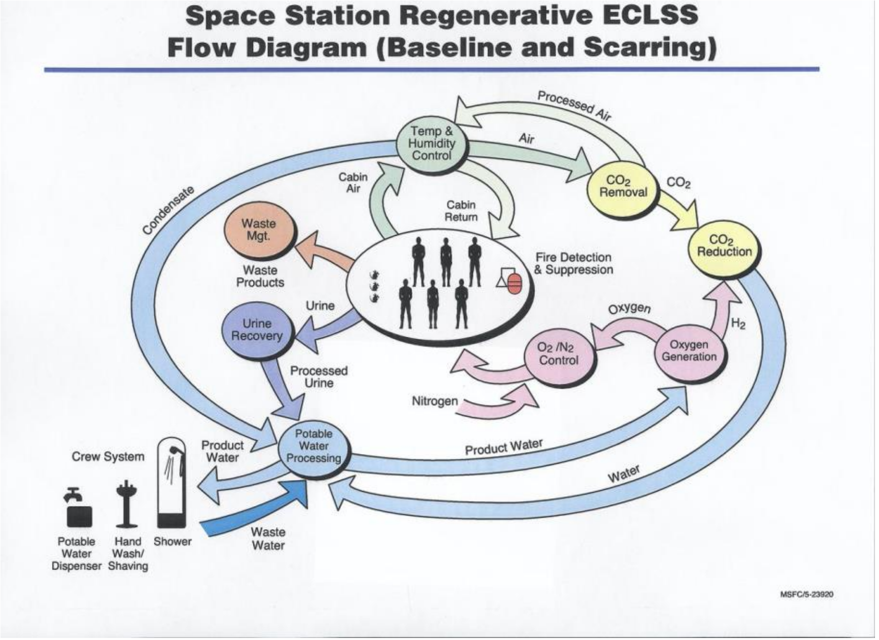
Crewed space missions → the challenges:

- Space vehicle
- Instruments reliability
- Wastes reusability

Needs:

ECLSS (Environment Controlled Life Support System)

→ As autonomous as possible



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I- Context Analysis (2)

Project MELiSSA (Micro-Ecological Life Support System Alternative)

- Transform a spaceship into a closed ecosystem
- Allow survival of a crew without regular reloading of resources from Earth.

Project of our team: preliminary conceptual design of a life support system

Mission towards Mars in the following conditions:

1000 days

4 astronauts

200m3 habitat

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I- Context Analysis (3)

Focus of the closed loop: autonomy

0%	← Solution studied →	100%
Resources = only from launch loads Drawbacks = Heavy load at the start	Challenges: • Recycled O2 > 75% • Recycled water > 98% Evaluation of the solution: ALiSSE criteria	Resources = only produced onboard Drawbacks = Technologically impossible for now

I- State of the art (1)

Systems and Technology Demonstrators used onboard ISS:

ACLS	Production of O2 from CO2	Atmosphere
ANITA	Cabin atmosphere analysis	Atmosphere
MIDASS	Verify cabin air quality (contaminations)	Atmosphere
OGA	Produce O2 from water	Atmosphere

UPA	Création d'eau distillée à partir d'urine pré-traitée	Water
WPA	Produce potable water from distilled and condensed water	Water
WRS	UPA + WPA	Wate
BPA	Treats brine	Water

In space additive manufacturing	3D impression	Maintenance

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I- State of the art (2)

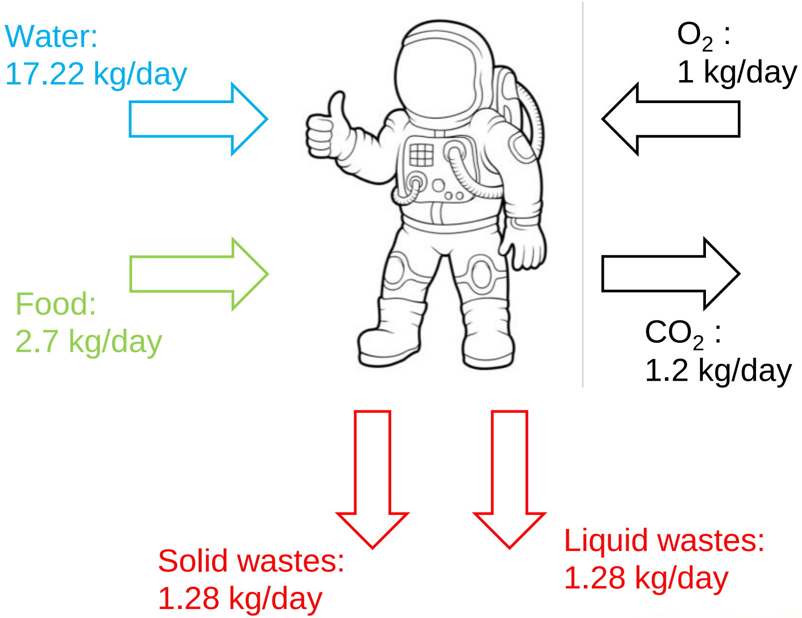
Technologies developed by MELiSSA:

BIORAT 1	Regeneration of part of the ISS cabin air by capturing carbon dioxide (CO2) and releasing back oxygen (O2) and food complement (proteins)	Food and atmosphere
BIORAT 2	Urine nitrification	Water
PFPU	Tubers production	Food
BELLISSIMA	Waste recycling (feaces, paper, food)	Wastes

II- Methodology

II- Needs and technical requirements

Needs:



Requirements:

- Derived directly from the needs and crucial step.
- Have to be fulfilled!
- Separated between design and functional requirements.

Examples :

- Habitat volume of $200m^3$
- Possibility to shower regularly

- Assure quality of water/air/food
- Treat at least 4.18 kg of water per day
- Be capable to grow plants

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II- Evaluation method (1)

ALiSSE criteria

- MASS
  - Material mass
  - Stocks mass
  - Logistic mass
- POWER
  - Primary power (external and loaded sources)
  - Secondary power (electric, thermic and light)
  - Tertiary power
- EFFICIENCY
  - Recycling rate (brut or effective)
  - Numbers of cycles
  - Self-sufficiency (in days)
  - Intensity of resource consumption
- RISK
  - Functional
  - Linked to extreme environment
  - For the environment
- CREW TIME
  - Handling
  - Training Material mass
  - Stocks mass
  - Logistic mass
  - Maintenance and repair

Advanced **Li**fe **S**upport **S**ystem **E**valuation

II- Evaluation method (1)

EFFICIENCY

Efficiency of the ECLSS: $\frac{r_p(X)+r_c(X)}{p(X)}$

Recycling rate of the ECLSS: $1 - \frac{w_p(X)+w_{c(X)}}{r_p(X)+r_c(X)}$

P: production term; r: resource term; w: waste term

MASS

Computed by comparison to ISS mass

SAFETY/SECURITY

Qualitative evaluation

POWER

Computed by comparison to ISS power consumption

$$S_{power} = -0.46\, P_c + 20$$

CREW TIME

Qualitative evaluation

II- Sub-systems definition

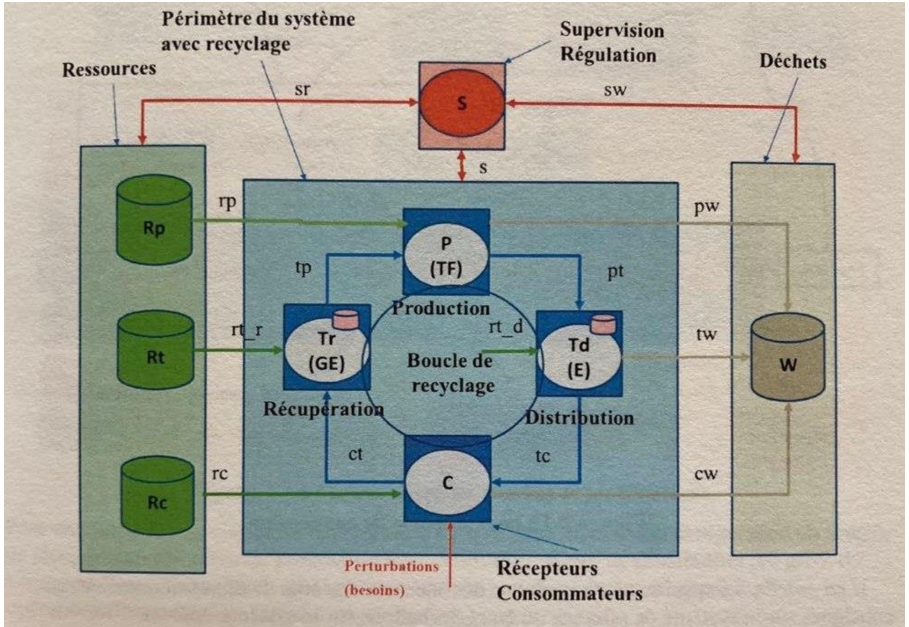

Figure 2-12 : EOF d'un système circulaire

- **Water** management
- **Food** management
- **Atmosphere** management
- **Wastes** management

III- Results and discussion

III- Subsystems' analysis: Water (1)

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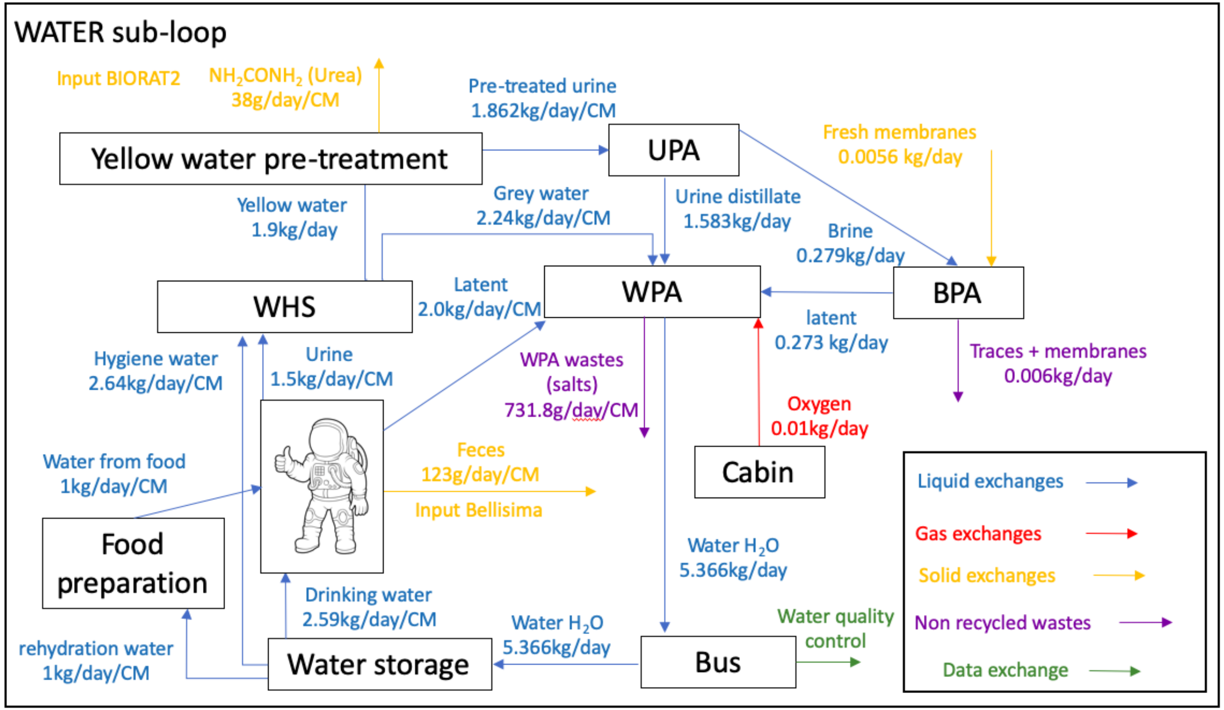
Objective: produce potable water from liquid wastes fluxes.

Challenges:

- $\eta_{rec} = 0.91$ (< 98% !)
- Low estimated efficiency of the WPA (88%)
- Continuous production of wastes (WPA and BPA)
- Yellow water pre-treatment



III- Subsystems' analysis: Atmosphere (2)

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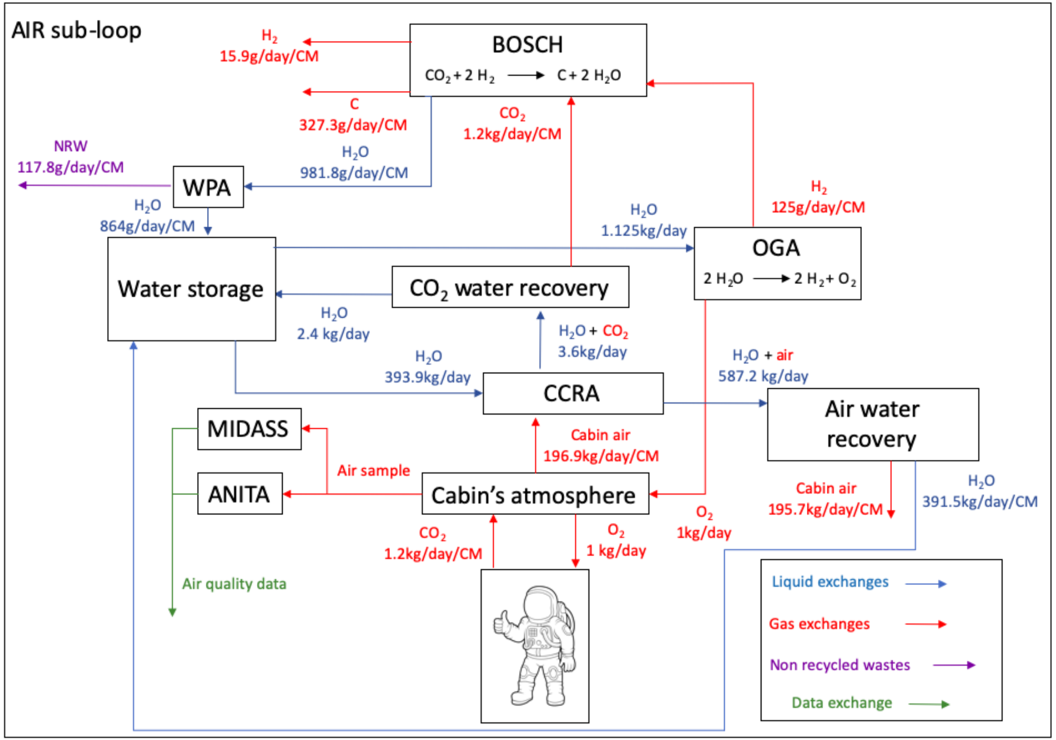
Objective: produce the oxygen needed and absorb associated carbon dioxide emissions.

Challenges:

- Important water consumption of the OGA
- Continuous production of wastes through water treatment in the WPA
- Production of solid carbon in the BOSCH reaction
- Surplus of dihydrogen in BOSCH reaction

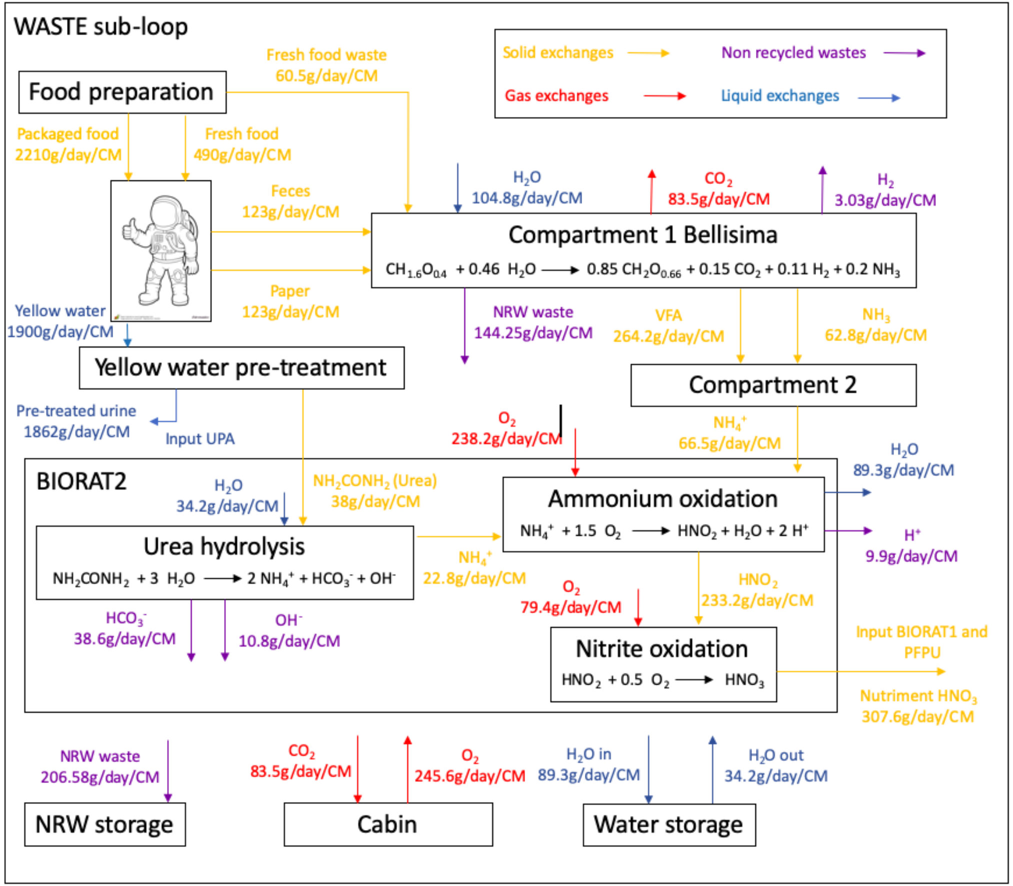


III- Subsystems' analysis: Wastes (3)

Objective: produce nutrients for the food loop from wastes.

Challenges:

- Production of CO2 and consumption of O2 in BIORAT2
- Continuous production of wastes to store
- Some wastes are not considered in this loop (no additive manufacturing, hygienic protection, clothes…)



III- Subsystems' analysis: Food (4)

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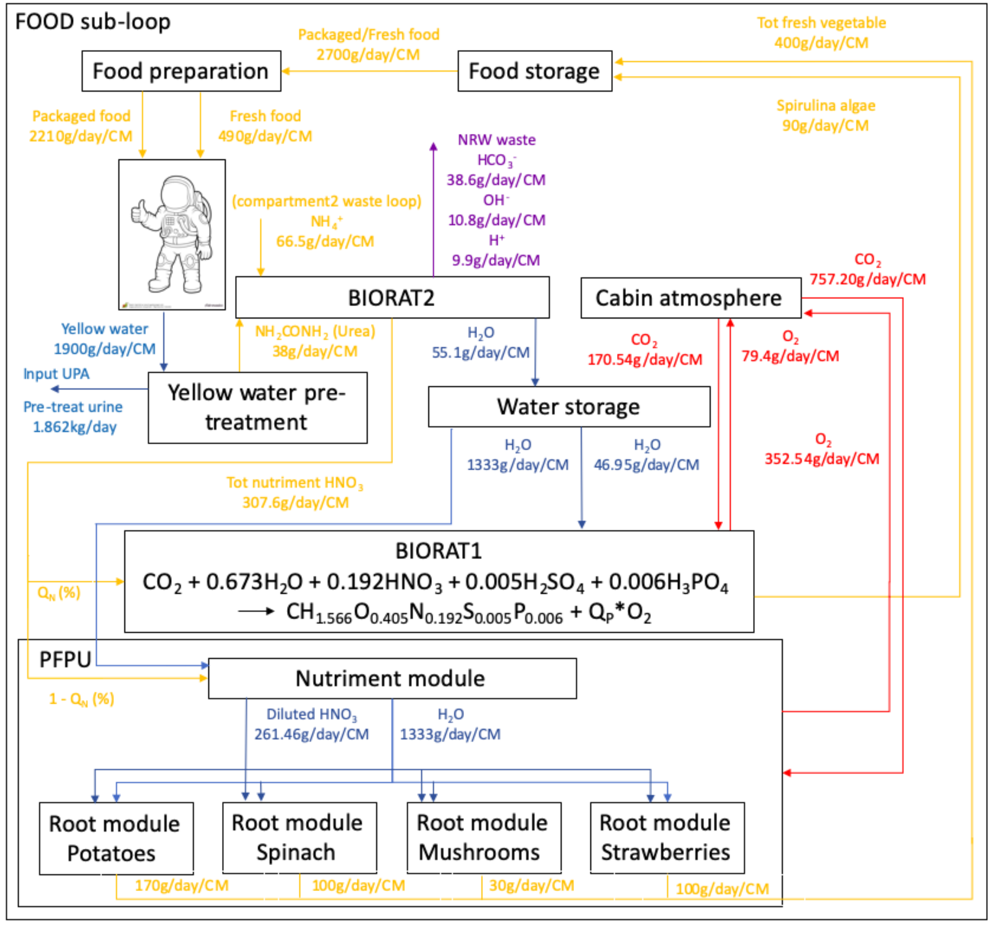
Objective: Offer a source of edible biomass.

Challenges:

- Limited to 50% of the daily needs of the astronauts (possibility to stored at the beginning of the mission)
- Important water consumption by PFPU and BIORAT 1.
- Continuous production of wastes to store.



III- Closed loop (1)

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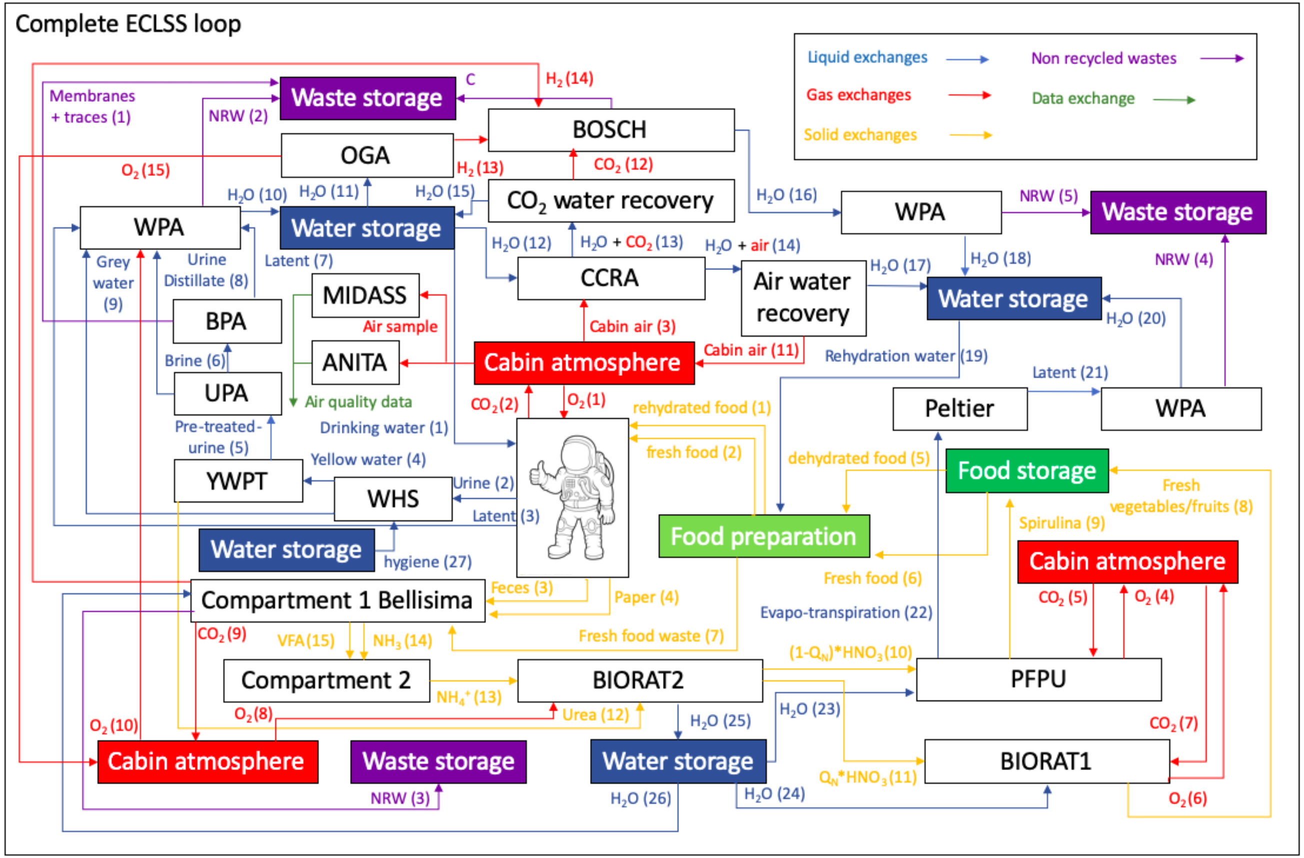
Solid exchanges	
#	g/day/CM
1	2210
2	490
3	123
4	123
5	1210
6	490
7	60.5
8	400
9	90
10	261.46
11	46.14
12	38
13	66.5
14	62.8
15	264.2

Gas exchanges	
#	g/day/CM
1	1000
2	1200
3	196 900
4	352.4
5	757.2
6	74.4
7	170.54
8	245.6
9	83.5
10	10
11	195 700
12	1200
13	106.7
14	3.03
15	529

Liquid exchanges			
#	g/day/CM	#	g/day/CM
1	2590	16	981.8
2	1500	17	391 500
3	2000	18	864
4	1900	19	1000
5	1862	20	1055.7
6	279	21	1170
7	273	22	1170
8	1583	23	1333
9	2240	24	46.9
10	5366	25	89.3
11	1125	26	104.8
12	393 900	27	2640
13	3600		
14	587 200		
15	2400		

Waste exchanges	
#	g/day/CM
1	60
2	731.72
3	144.25
4	140
5	74.65



III- Closed loop (2)

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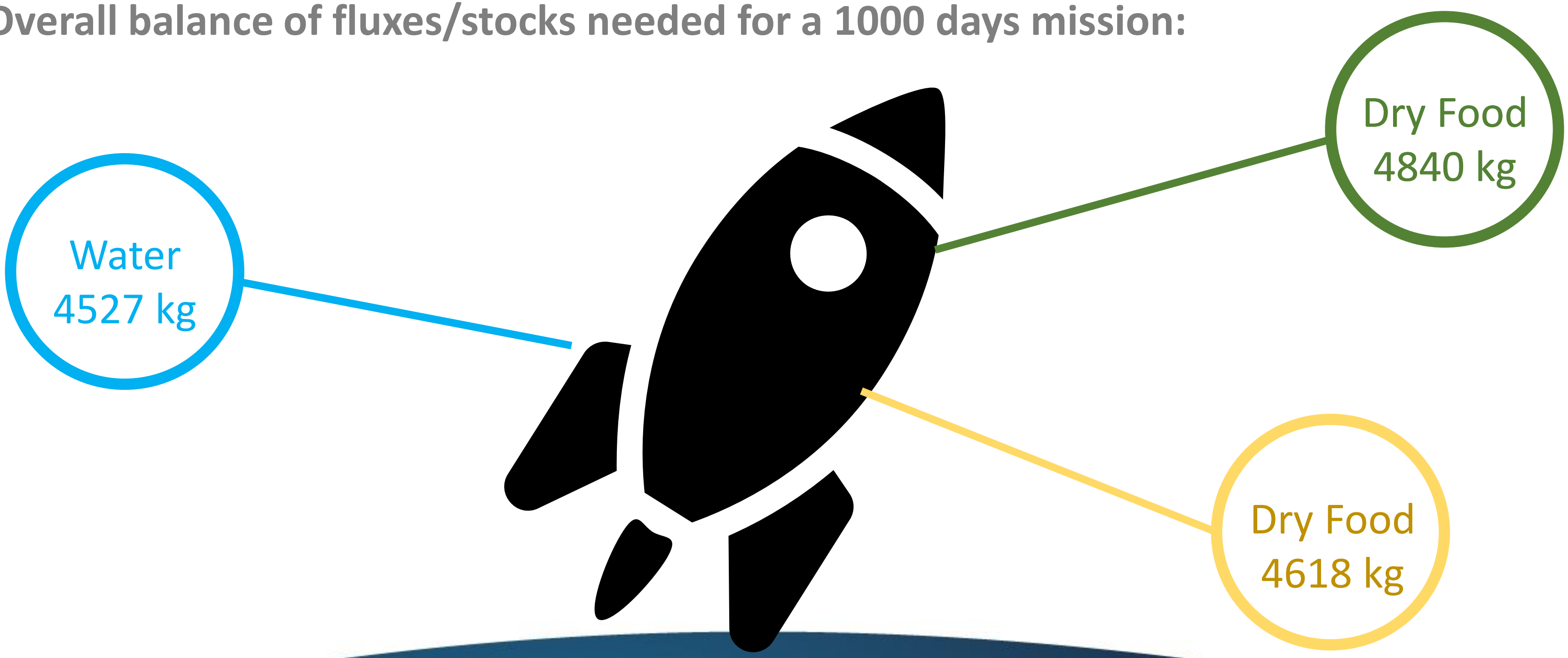
Overall balance of fluxes/stocks needed for a 1000 days mission:



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III-ALISSE evaluation (1)

Mass:

- Total mass of the system: 4842 kg
- Most of the mass comes from BIORAT1 and PFPU subsystems
- Balanced with the loaded mass

Note: 6/10

Crew time:

- Both repetitive tasks and one time operation taken into account

Note: 7/10

Safety/Security:

- High impact of the Technology Readiness Level (TRL)
- Unsafety induced by the utilization of PFPU for most of the fresh food (Efficiency favored)

Note: 4/10

III- ALISSE evaluation (2)

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Power:

- Total score of 4.9
- Computed by estimation and scaling from existing demonstrator

Note: 4.9/10

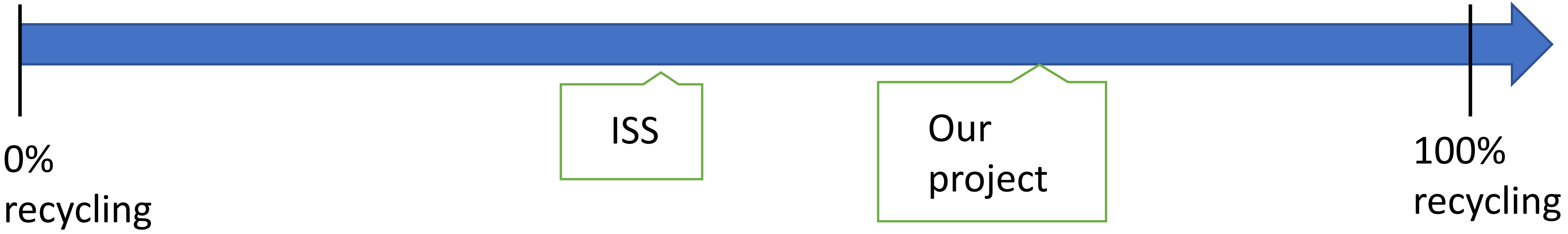
Efficiency:

- Oxygen and hydrogen recycling rate
- Criteria that was given the advantage in many compromises

Note: 9.3/10

The most optimized criteria is efficiency, however there are still a lot of improvements to do to make it a light and safe system.

III- Conclusion



Optimization possibilities:

- Improvement of technology efficiency
- Optimization of requirements and needs
- Refine hypothesis
- Improve ALISSE criteria definition

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THANK YOU.

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