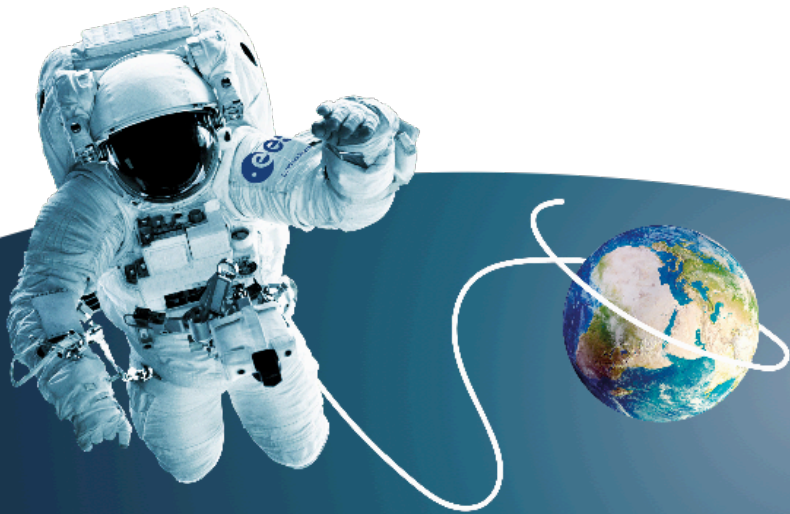# Development status of the nutrient delivery system of PFPU, Precursor of microgravity Food Production Unit

Giorgio Boscheri
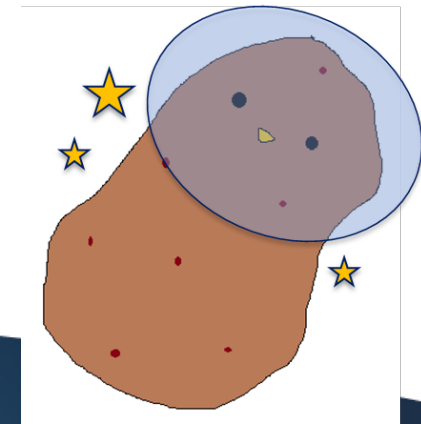
Thales Alenia Space

MELISSA
MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
ALTERNATIVE
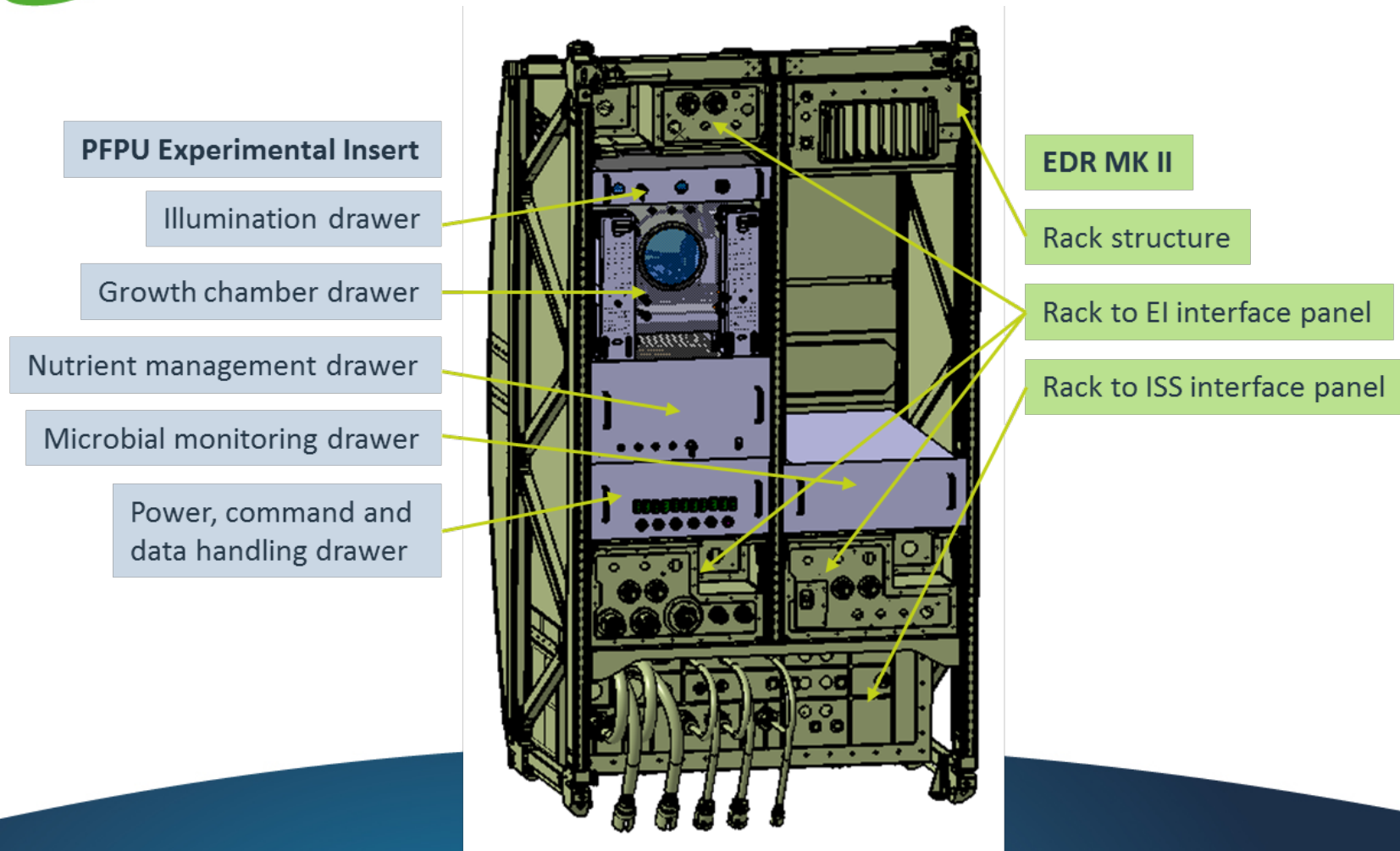
CREATING
A CIRCULAR
FUTURE

What is PFPU?

- MELiSSA project

- Micro-gravity technology demonstrator

- Controlled production of edible tuberous plants from tuber-seed to ready-to-harvest tubers

- Highly modular, allowing compartmentalization into independent, self-contained, process-specific modules

- Step-wise development approach

PFPU overview

PFPU Experimental Insert

Illumination drawer

Growth chamber drawer

Nutrient management drawer

Microbial monitoring drawer

Power, command and data handling drawer

EDR MK II

Rack structure

Rack to EI interface panel
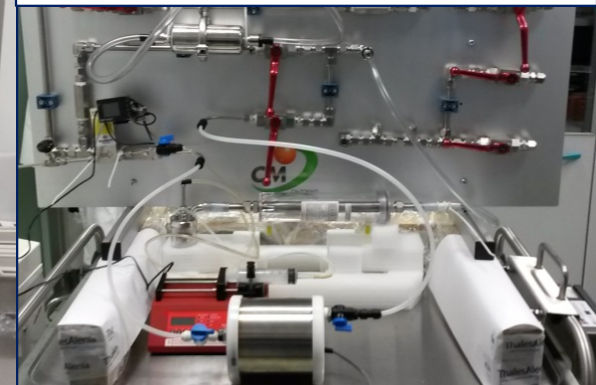
Rack to ISS interface panel

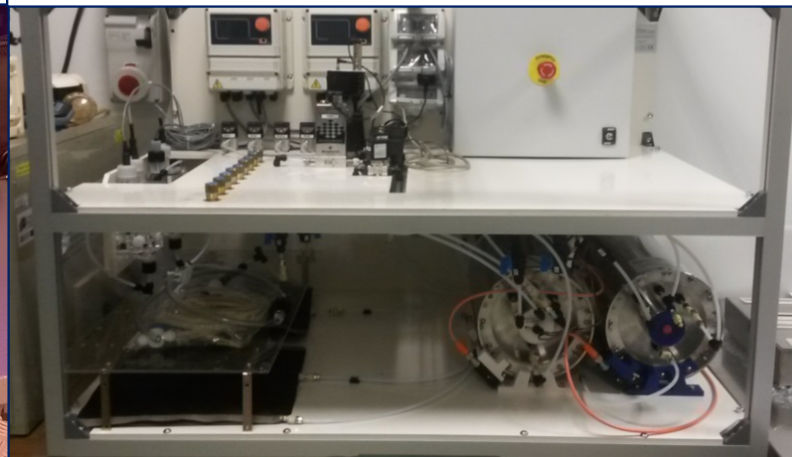# PFPU Ongoing Developments

ROOT MODULE

NUTRIENT MODULE

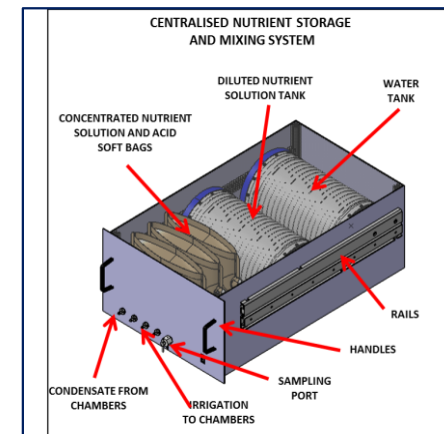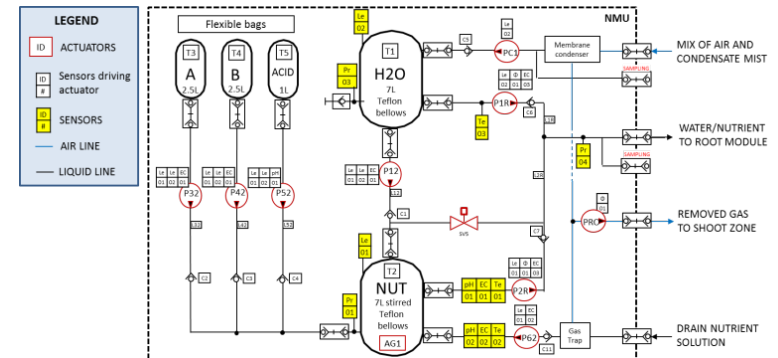MICROBIAL CONTAMINATION CONTROL MODULE

PFPU Nutrient Delivery System

MAIN FUNCTIONS

- Provide nutrient solution to the root zone

- Provide DI water to the root zone

- Provide air to the tuber zone

- Degas and Store recovered condensate

- Mix and monitor nutrient solution in situ

PFPU Nutrient Delivery System
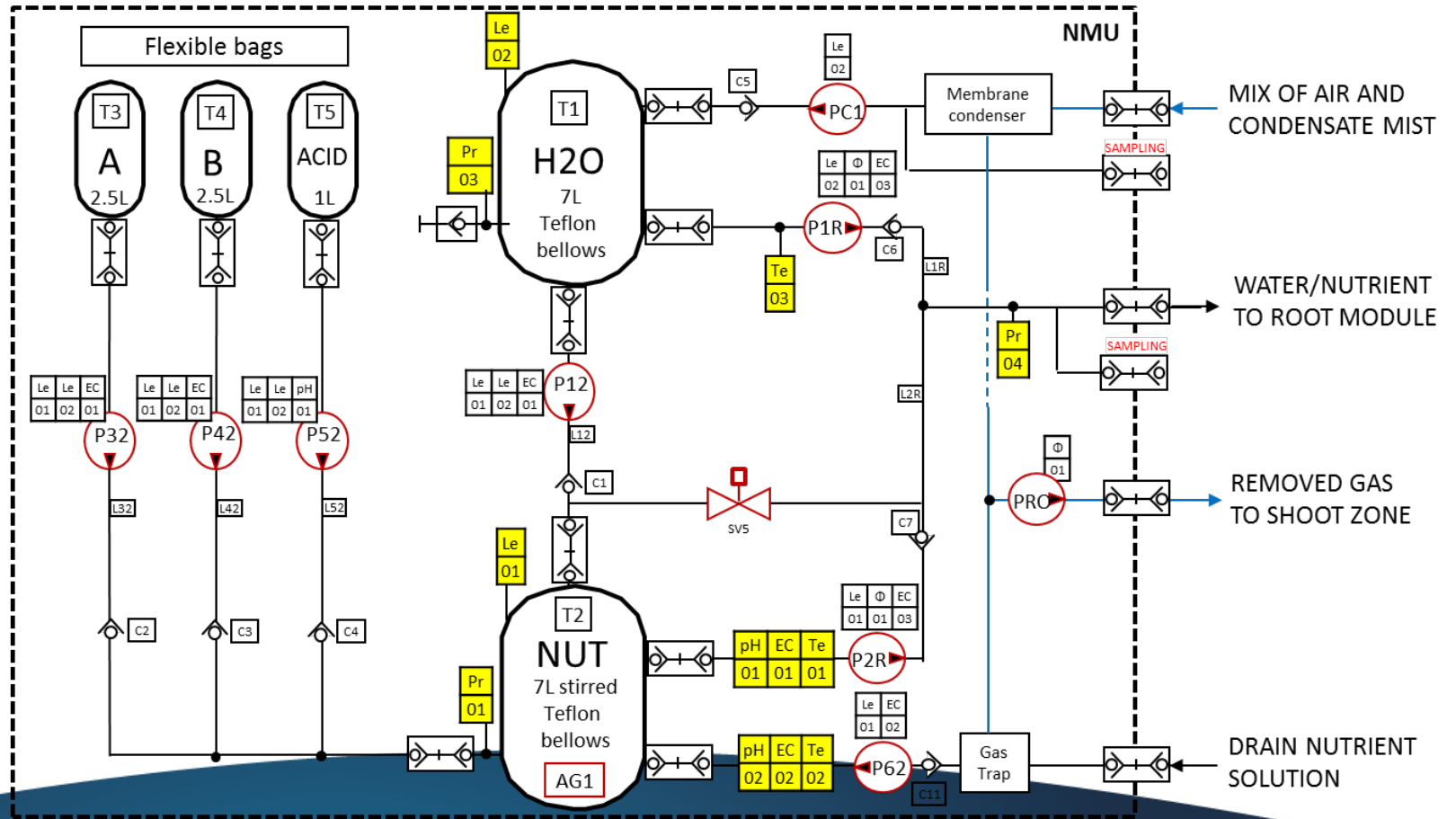
PFPU Nutrient Delivery System

Custom units

Bellows reservoir (7L)
Flexible/soft bag (1L)
Membrane degasser
Membrane condenser
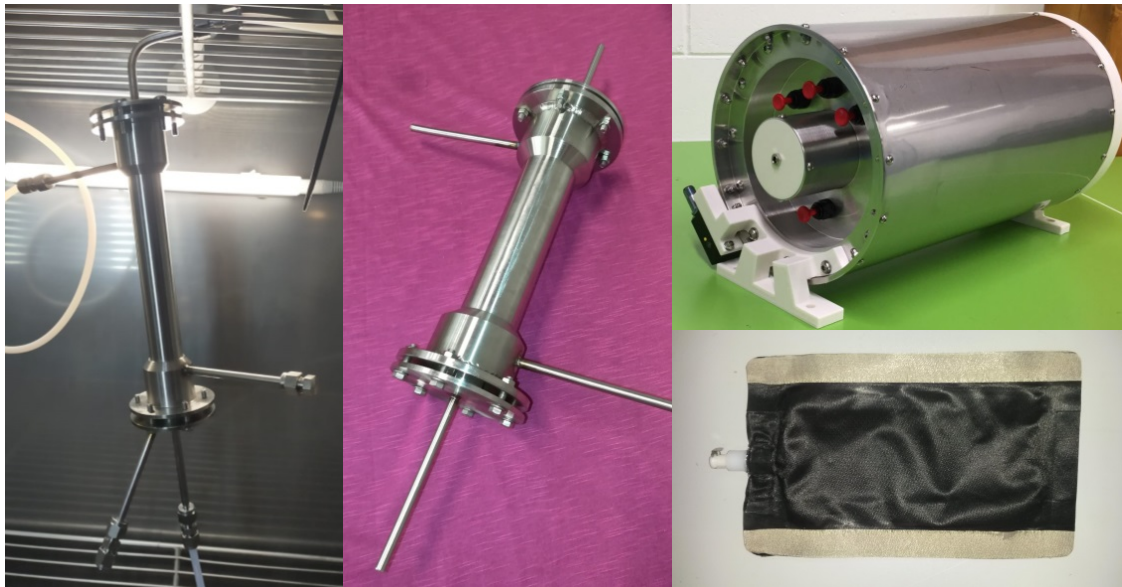
COTS units

Sensors:
- pH
- Water level
- EC
- Temperature
- Pressure

Actuators:
- Pump (delivery)
- Pump (dosing)
- Stirrer

COTS pH sensor

Main perf. requirements
- pH range: 5.5 – 6.5
- pH accuracy: 0.3 at EoL
- Water EC range: 0.2 – 2.0 mS/cm
- Time w/o calibration: 5 months

Tested sensors

Potentiometric
- Endress Hauser Memosens CPS97D
- Mettler Toledo InPro 4281i

Optical
- PreSens PH-1 mini v2
- Pyroscience PHROB-PK6-CL2

COTS pH sensor

pH measurement drift over time (start@ EC ~0.2mS/cm - pH ~6)

Legend:
- Presens pH-1 mini v2 (optical)
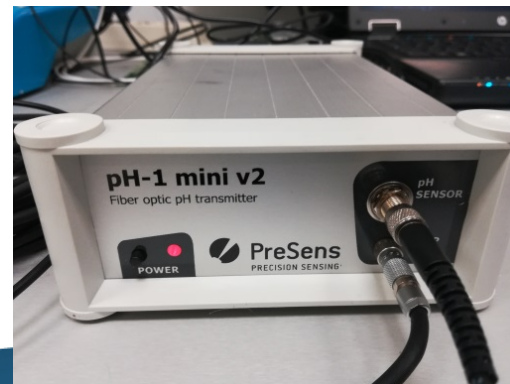- Pyroscience PHROB-PK6-CL2 (optical)
- Mettler Toledo InPro 4281i (potentiometric)
- Endress Hauser Memosens CPS97D (potentiometric)

X-axis: Days from test start
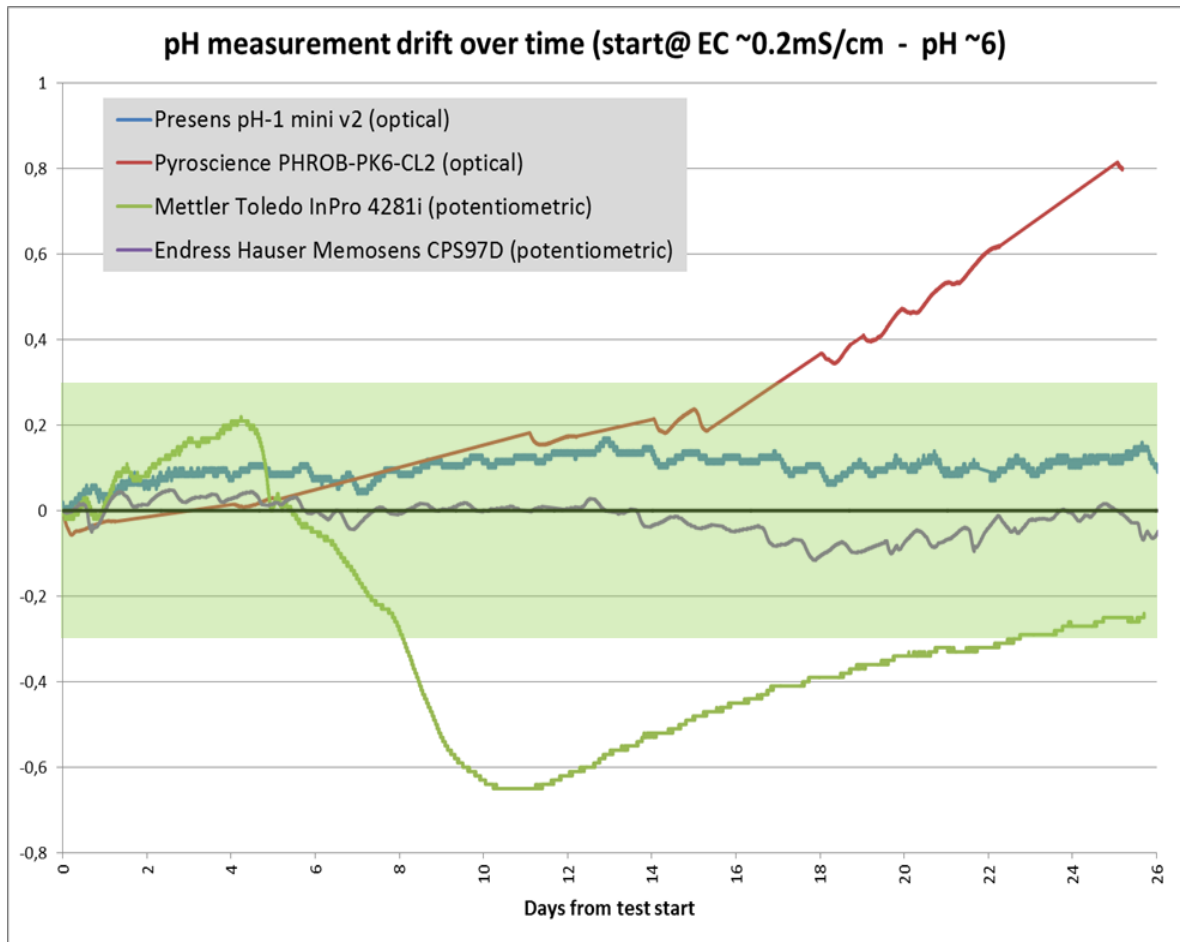
	Test campaign @0.2mS/cm	Test campaign @0.5mS/cm	Functional criticalities
Endress Hauser Memosens CPS97D	Acceptable	Acceptable	Gel reference depletion
Mettler Toledo InPro 4281i	Not acceptable	Acceptable	Difficult recovery from microbial contamination
PreSens PH-1 mini v2	Acceptable	Acceptable	None identified
Pyroscience PHROB-PK6-CL2	Not acceptable	Acceptable	Sensor spot detachment

PreSens optical sensor selected as baseline

COTS water level sensor

Main perf. requirements

- Measure bellows reservoir bottom plate displacement up to 25cm
- Accuracy: 0.3 mm (~10ml)
- Minimize reservoir envelope impact

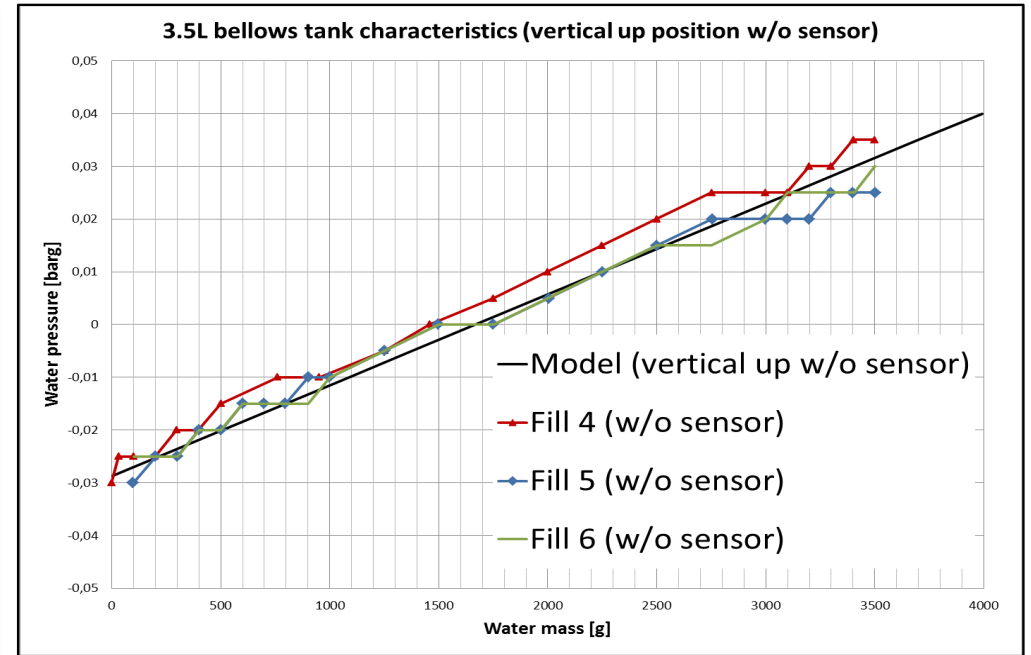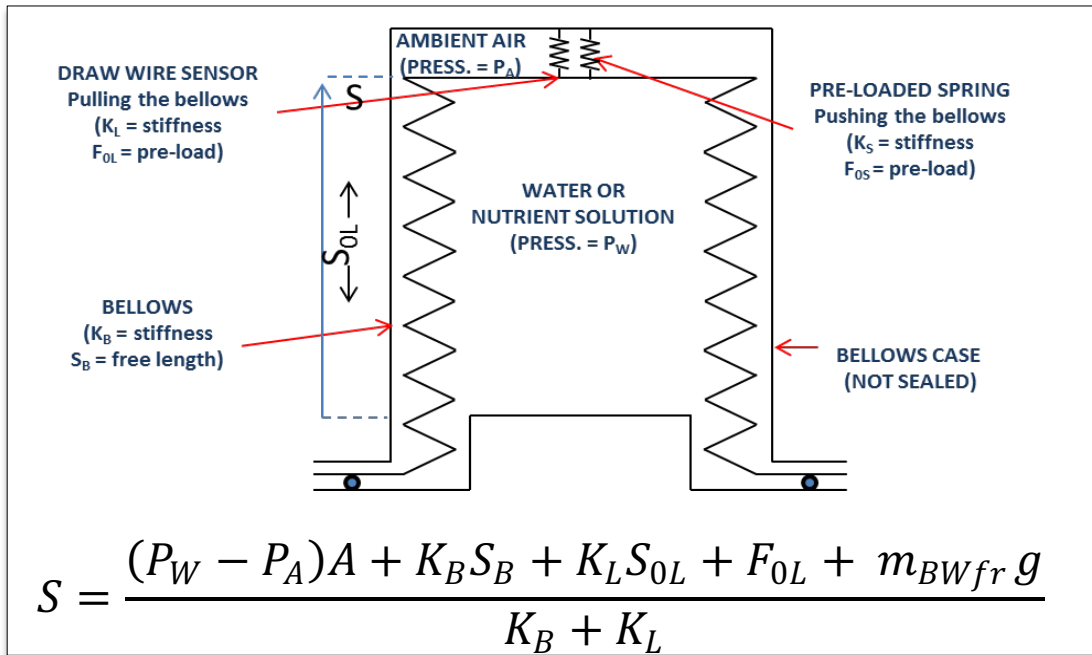## Tested sensors

Laser Displacement Sensor
- More compact
- Space qualified unit not available

Draw Wire Sensor
- Less compact
- Space qualified unit available

COTS water level sensor

$$S = \frac{(P_W - P_A)A + K_B S_B + K_L S_{0L} + F_{0L} + m_{BWfr}\, g}{K_B + K_L}$$

Both sensor capable of allowing acceptable evaluation of the bellows reservoir water level during both fill and drain cycles

COTS water pumps

It is possible to cover the NDS water pumping needs (7 pumps) with **only two different units** (**one** is used **in 2 different operative configurations**)

Pump ID.	Pump Model	Water Source	Water Destination	Performance @ 25±5°C	Performance @ 45±5°C
P32/P42/P52	Variable volume dispense pump p/n **LPDA1750330H**	T3/T4/T5 Conc. Nut. Sol	T2 Diluted Nut. Sol.	Accurate dispensing in the range 0.1-3 ml	Accurate dispensing in the range 0.1-3 ml
P12	Variable volume dispense pump p/n **LPDA1750330H**	T1 D.I.Water Tank	T2 Diluted Nut. Sol.	> 45 ml/min	> 45 ml/min
P51	Variable volume dispense pump p/n **LPDA1750330H**	T5 Beker	T1 D.I.Water Tank	> 45 ml/min	> 45 ml/min
P2R/1R	Fixed volume solenoid Pump p/n **LPGA2450618D**	T2 Diluted Nut. Sol.	T4 Porous plate	> 45 ml/min	> 45 ml/min

COTS stirrer

| Description	Time for solution mixing	Pro	Drawbacks
Stirrer + Diffusion	<15s	Mass +	EC value? No redundancy
Diffusion only	>2400s	Mass ++	Time - - EC value?
Recirculation Loop + Diffusion	<80s	Mass + EC value known	Time -
Stirrer + Diffusion + Recirculation Loop	<15s	EC value known Redundancy	Mass -
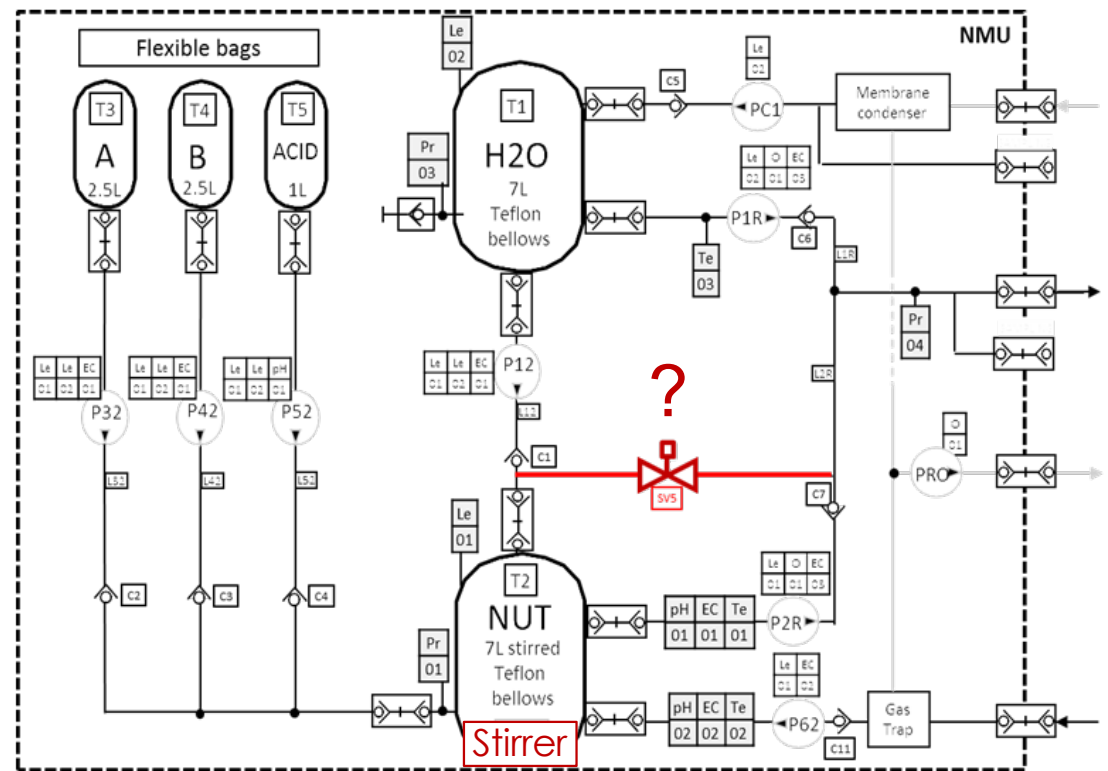
Current baseline includes both stirrer and recirculation loop

Phase-separation modules

Currently under
laboratory testing
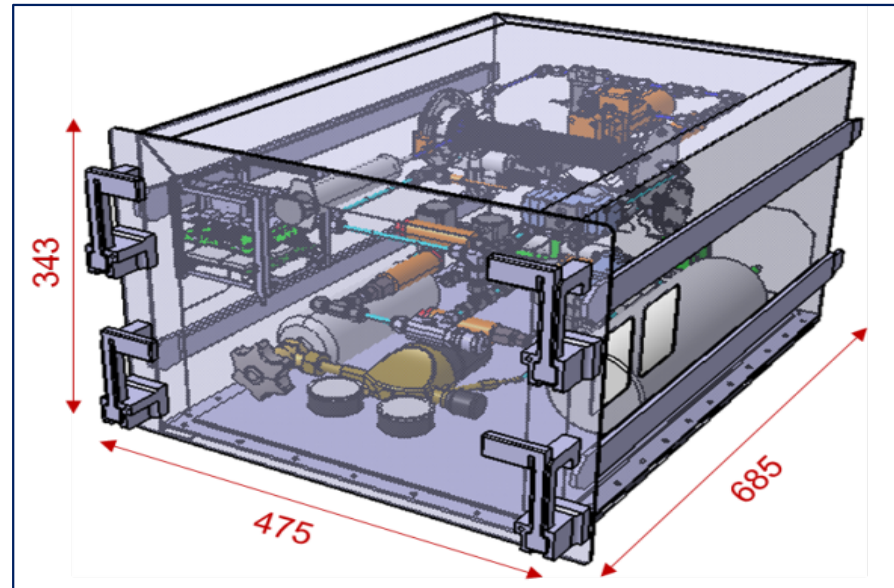
Microgravity demonstrator
conceptual design completed

343

475

685

PFPU - Future work (2021-22)

Module	Activity
Root Module	Test in relevant environment
Nutrient Module	Components verification toward space environmental loads
Illumination Module	Prototyping and testing
Growth Chamber	Prototyping and testing
Temperature Control Module	Prototyping and testing
System	Assembly of above modules for testing (with and w/o crops)

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LIFE SUPPORT SYSTEM
ALTERNATIVE

All presented activities were carried on within ESA contract No. 4000114057/14/NL/AT ,
In collaboration with the below project partners

THANK YOU.

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