MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

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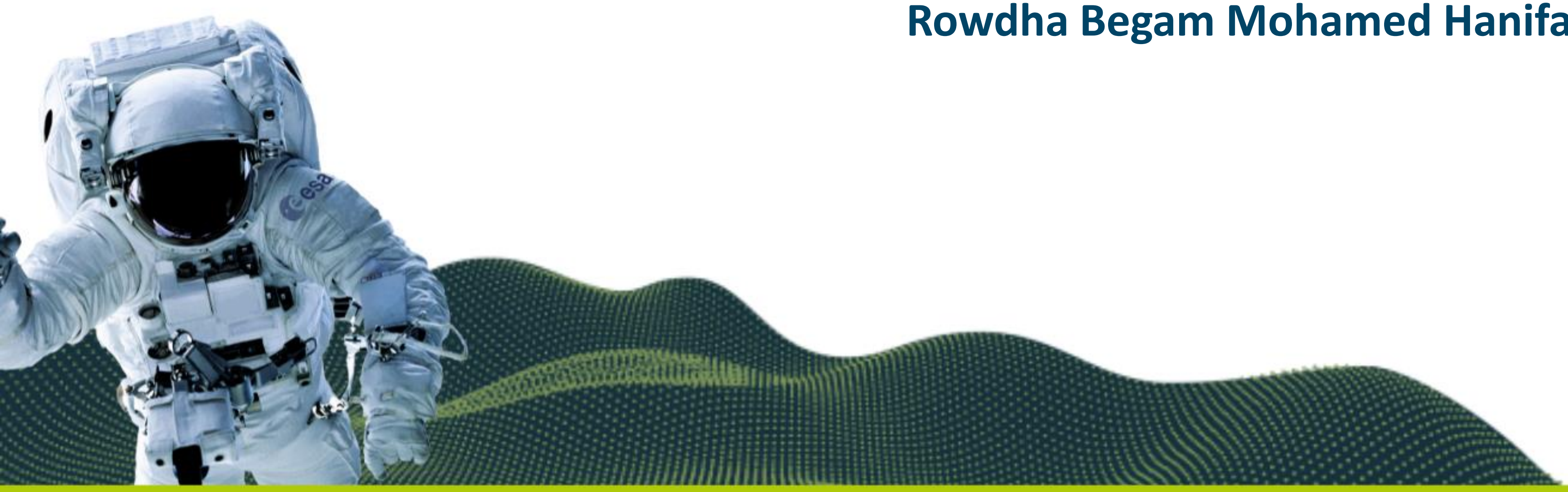
CREATING A CIRCULAR FUTURE

Concept Study of a BLSS Module for LEO, Cislunar and Mars Transit Stations

Paolo Caratelli, Peter Weiss, Maria Alessandra Misuri,
Rowdha Begam Mohamed Hanifa and Enaam Mohamed Ouda



Concept Study of a BLSS Module
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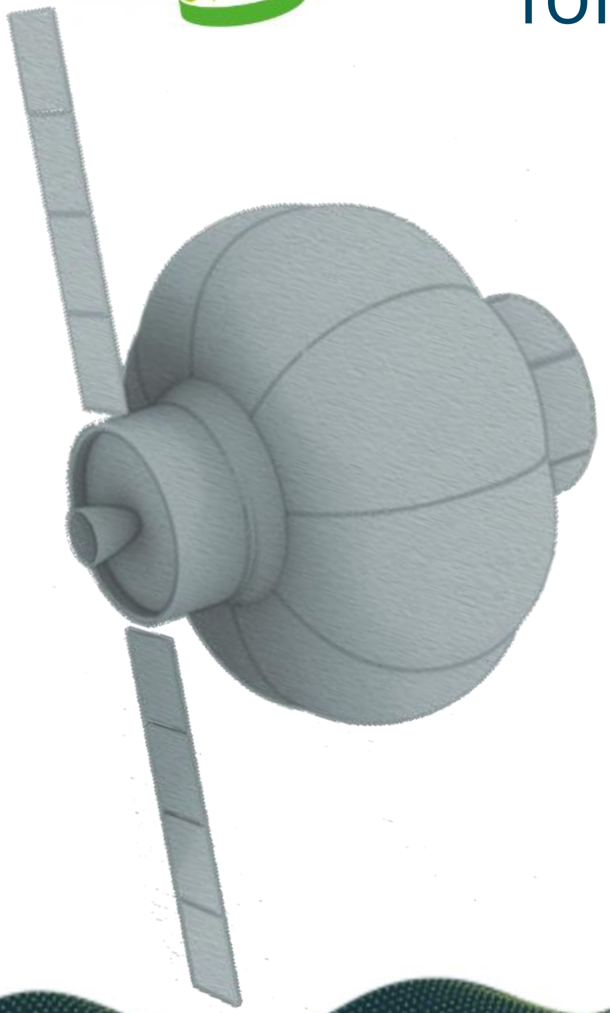

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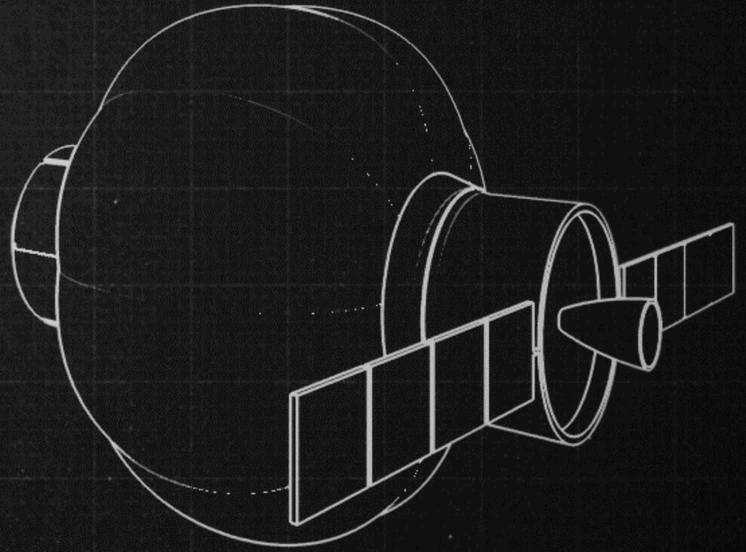
ABSTRACT

This paper explores the feasibility of A HYBRID RIGID/INFLATABLE LAB MODULE, based on the Cygnus spacecraft by Northrop Grumman Space Systems and Thales Alenia Space.

This expandable module would host an experimental greenhouse for plants, microalgae's photo-bioreactors, and the necessary BLSS hardware, adding capability to the ECLSS of the station.

Its scope is to evaluate the capability of carbon sequestration, OXYGEN REGENERATION, HUMIDITY CONDENSATION, WASTE PROCESSING, WASTEWATER RECYCLING AND FOOD PRODUCTION of the BLSS in conditions of microgravity.

Furthermore, it increases the habitable volume and introduces an element of TANGIBLE NATURAL BOND WITH THE HOME PLANET for crew's psychological support.



CONCEPT

The concept at its basis is the integration of bio-regenerative lifecycles to be paired with the life support systems installed onboard of DSTVs or orbital facilities, like the International Space Station (ISS), the Cislunar Gateway station, or future Commercial Orbital stations.

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PURPOSE

WATER PRODUCTION

FOOD PRODUCTION

OXYGEN REGENERATION

WATER REGENERATION

WASTE /WATER RECYCLE

CO2 SEQUESTRATION

REDUCE

REUSE

RECYCLE

The main purpose of the lab module is to test in extended real conditions the potential capability of biological systems to improve air and water regeneration, waste/wastewater recycling, and food production onboard a spacecraft with limited or no opportunity for resupply from external resources.

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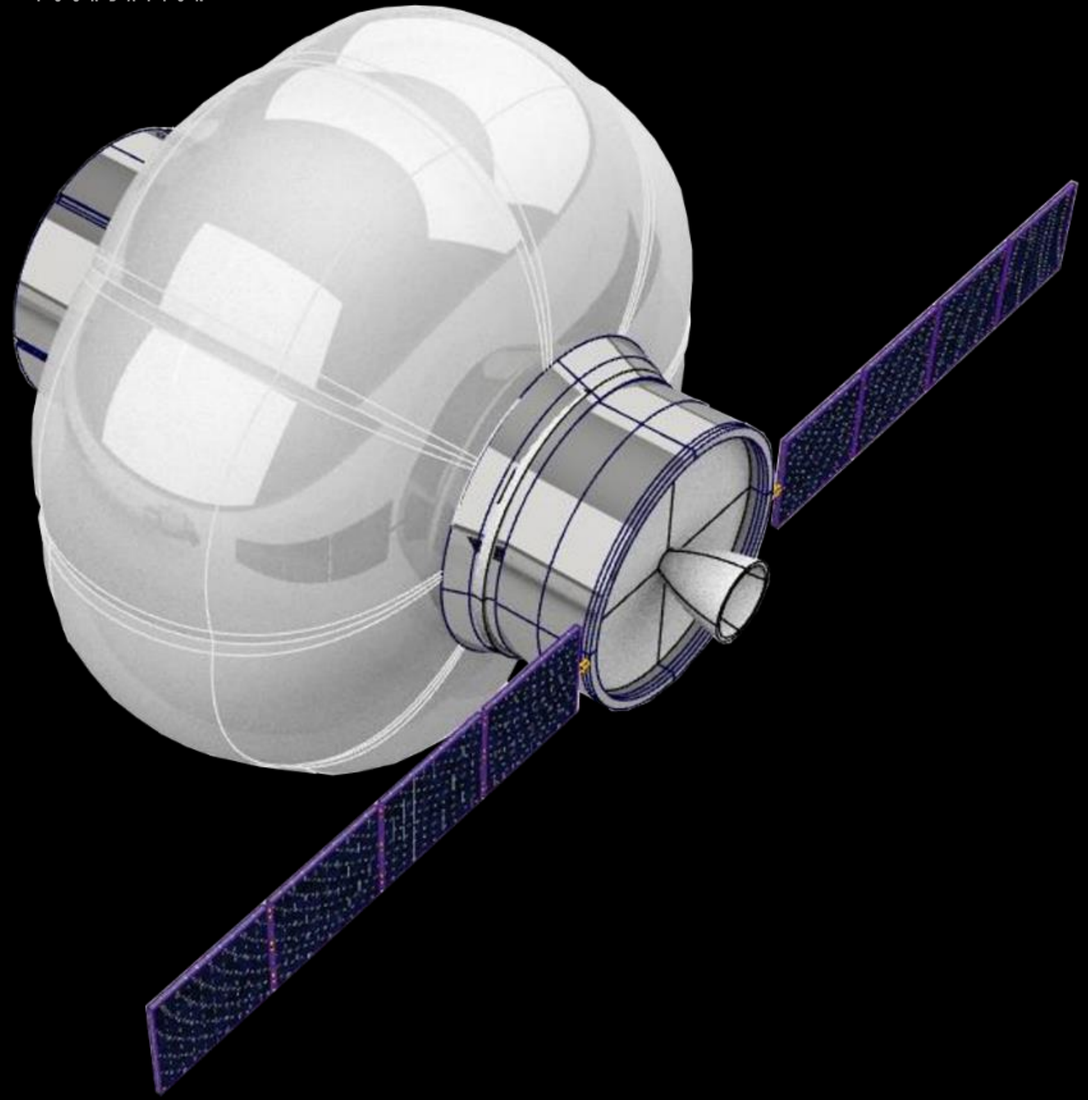
MODULE OVERVIEW



In our study, the original Class I structure of the module has been modified into a hybrid rigid/inflatable Class II module, keeping the same dimensions once in closed configuration at launch with an internal volume of 27 m^3.

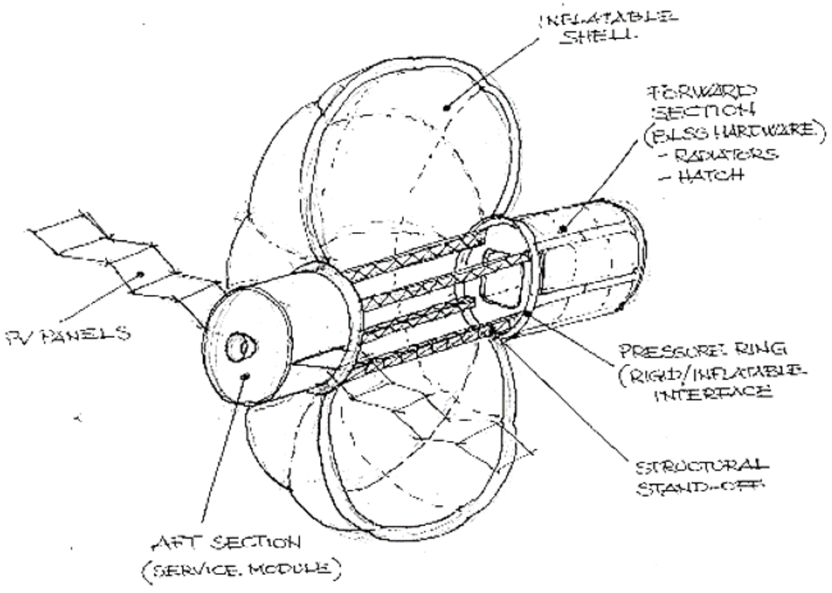
Following the same minimalist design philosophy of the original Cygnus project, the study evidenced the modular adaptability of this spacecraft.

The pressurized module will be equipped with a service module [SM] for power and propulsion, similarly to Cygnus cargo spacecraft,

Power generation is provided by two gallium arsenide solar arrays extended to four modules each, instead of the two Ultra flex arrays installed in latest Cygnus to avoid geometric interference with the inflatable shell.

Once docked to the station, the SM will provide additional power to greenhouse's systems, and could be used as a thruster for orbital maneuverability and backup energy source in case of an emergency

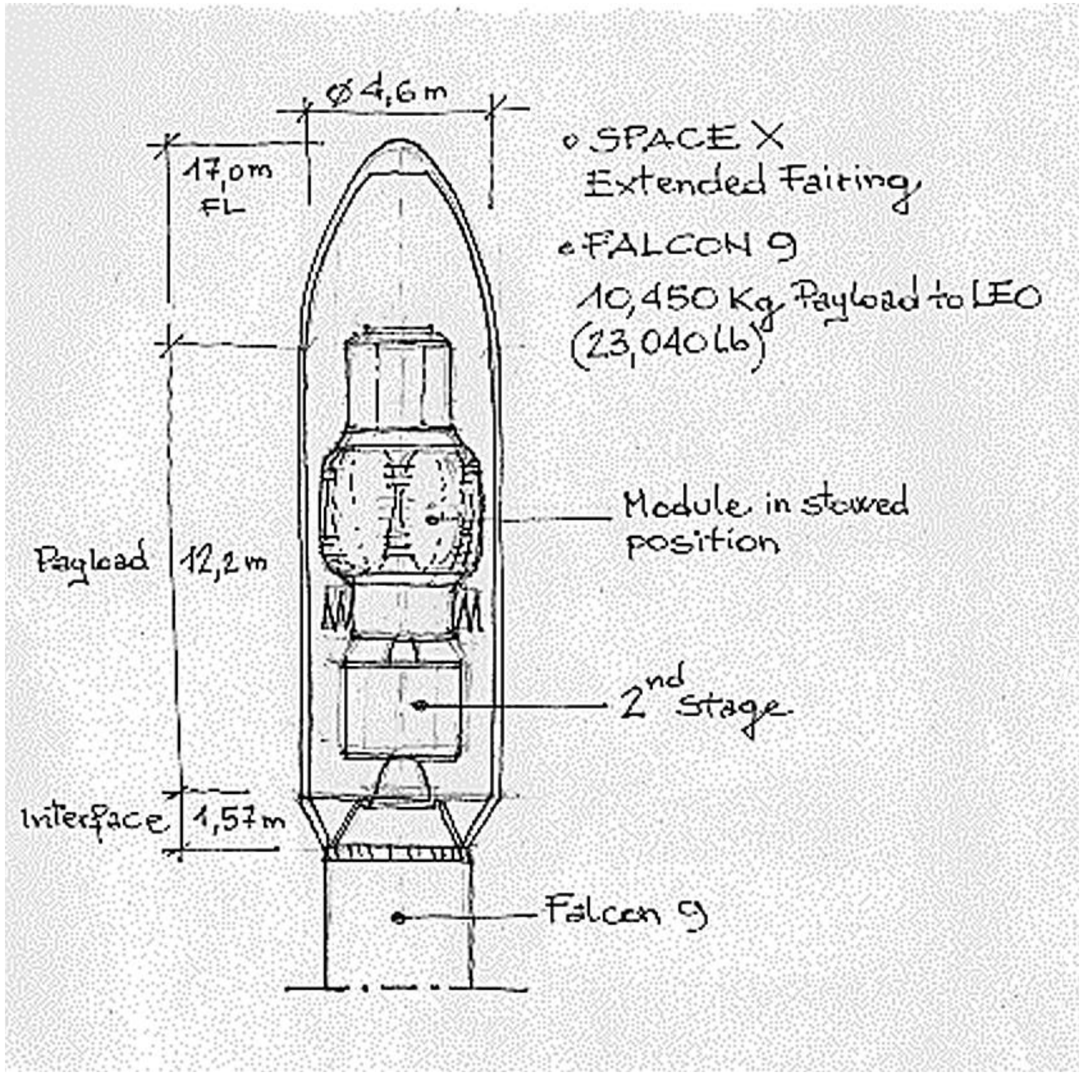
CONCEPT SKETCH



CYGNUS RIGID/INFLATABLE BLSS MODULE

- Launch Mass (estimated): 7700 kg
- Internal Volume: 27.16 m^3 (closed configuration)

  222.64 m^3 (deployed configuration)



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CONCEPT SKETCH

1 RIGID SECTION

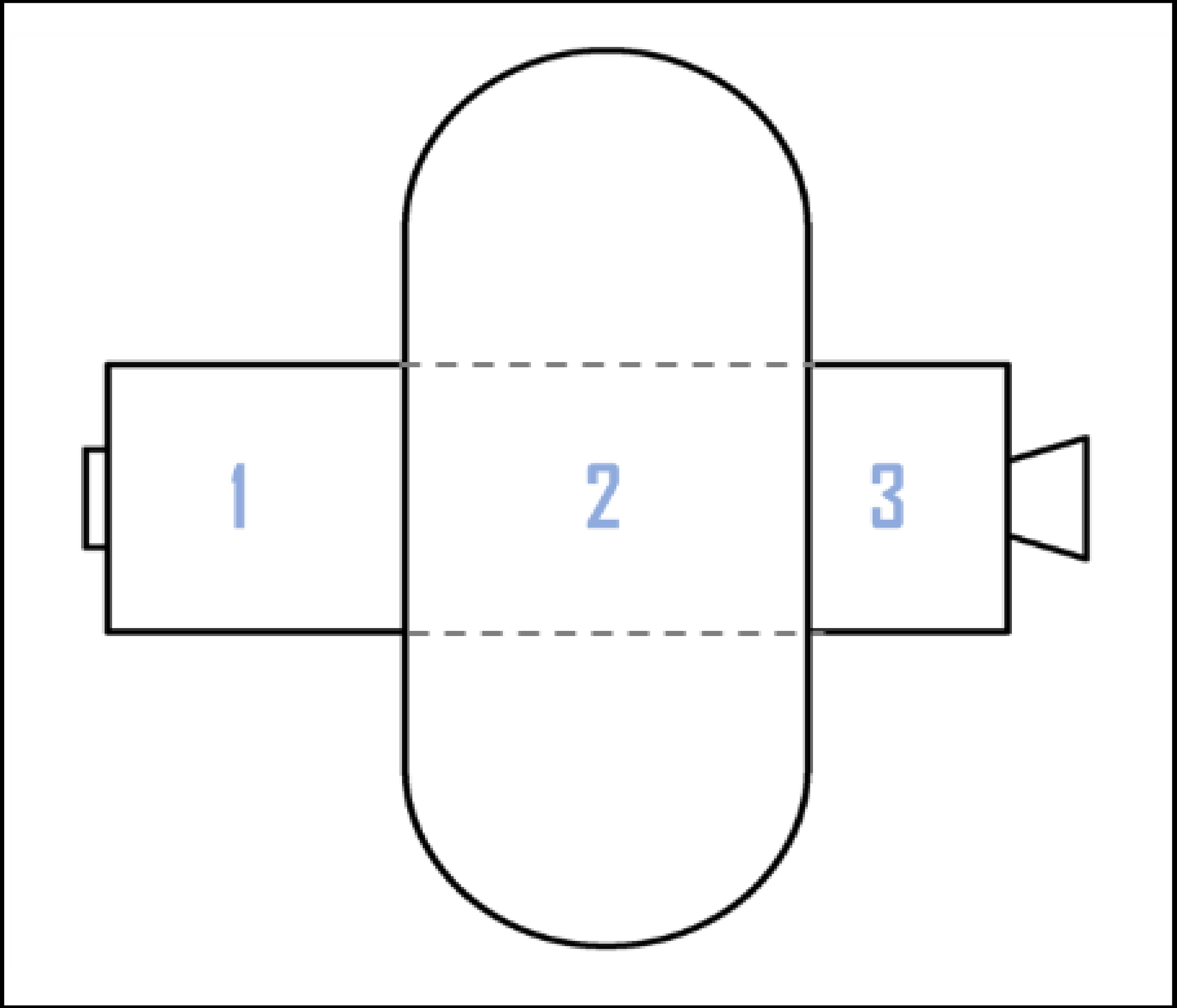
- Pressurized Volume: 11.78 m3
- Life Support System (BLSS)
- Internal Thermal Control Systems & Radiators
- Water Recovery
- Waste & Wastewater Management
- Docking System

2 INFLATABLE SECTION

- Volume: 15.38 m3 (closed, unpressurized),
- 195.48 m3 (deployed, pressurized)
- Greenhouse Racks
- Greenhouse Centrifuge
- Photo-bioreactors
- Photosynthetic Lighting System

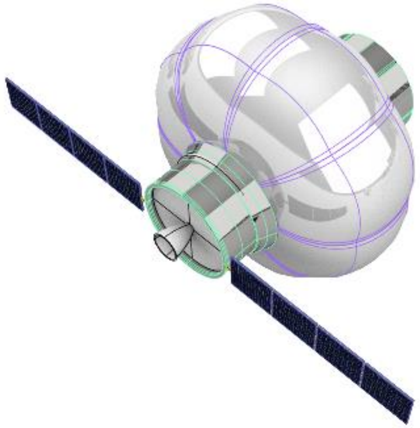
3 SERVICE MODULE

- Electrical Power System (PV Panels)
- Communications Systems
- RCS and Attitude/Trajectory Control
- Propulsion System
- Thermal Control

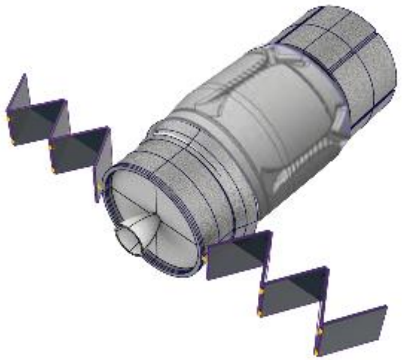


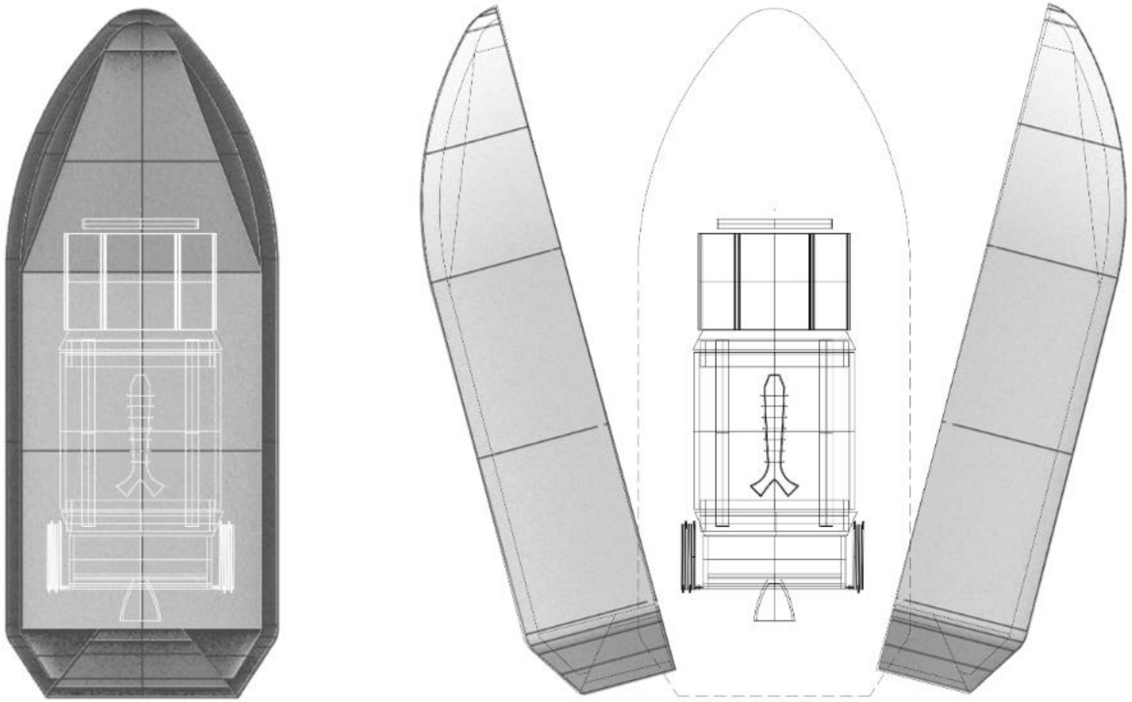
CONFIGURATION

SPACE X FAIRING - Image by SpaceX



OPEN CONFIGURATION AND INFLATABLE DEPLOYED



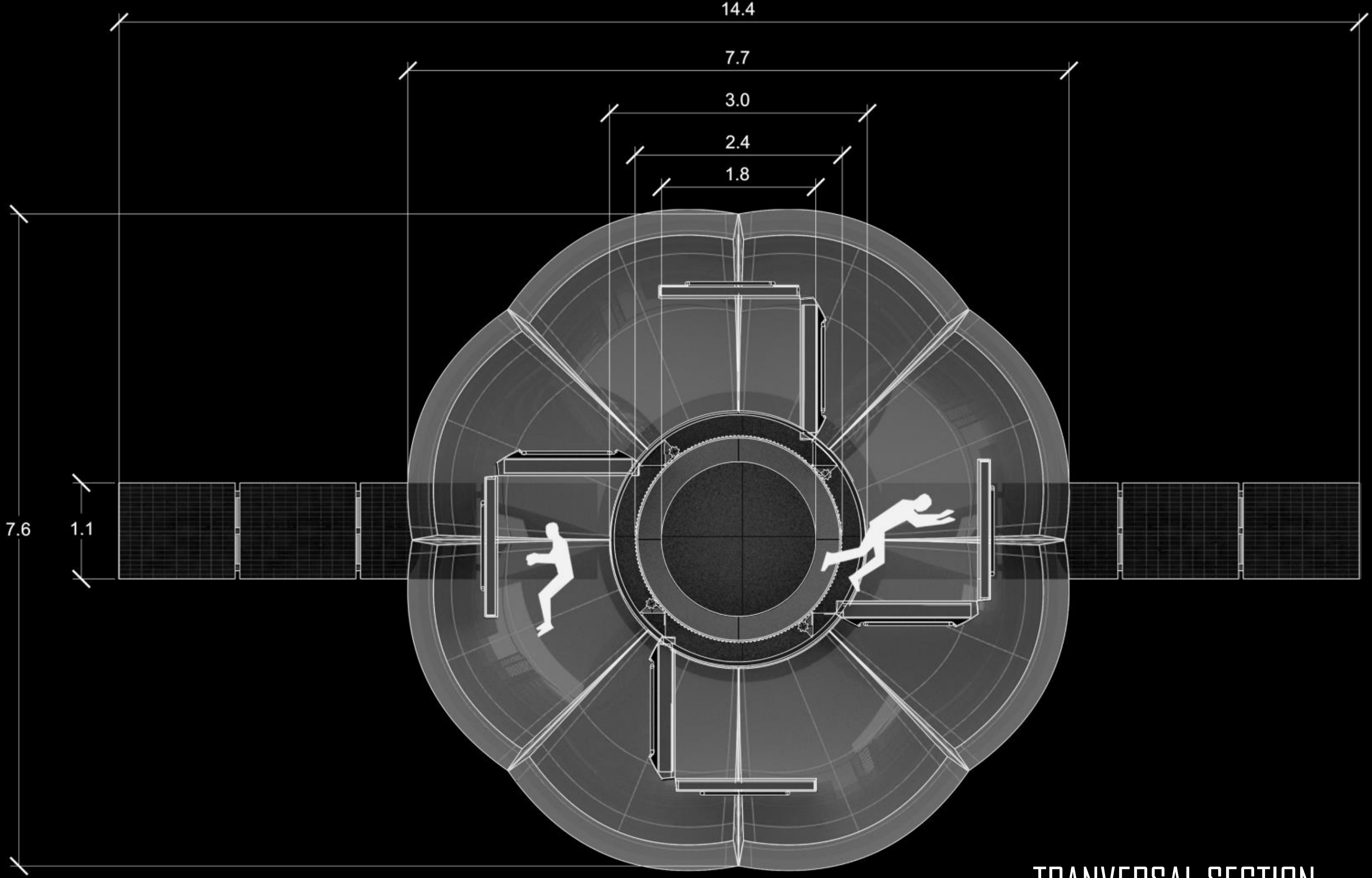


CLOSED CONFIGURATION PLACED IN THE SPACE X FAIRING

INTERNAL CONFIGURATION

This configuration offers an optimal degree of adaptability: racks can be easily removed and changed depending on the mission and the specific function assigned to the module.

The configuration proposed shows the adoption of four double-face foldable racks for aeroponic system and microalgae's photo-bioreactors, with LED lighting panels in between, providing the necessary amount of light to activate the biosynthesis process.



TRANVERSAL SECTION.

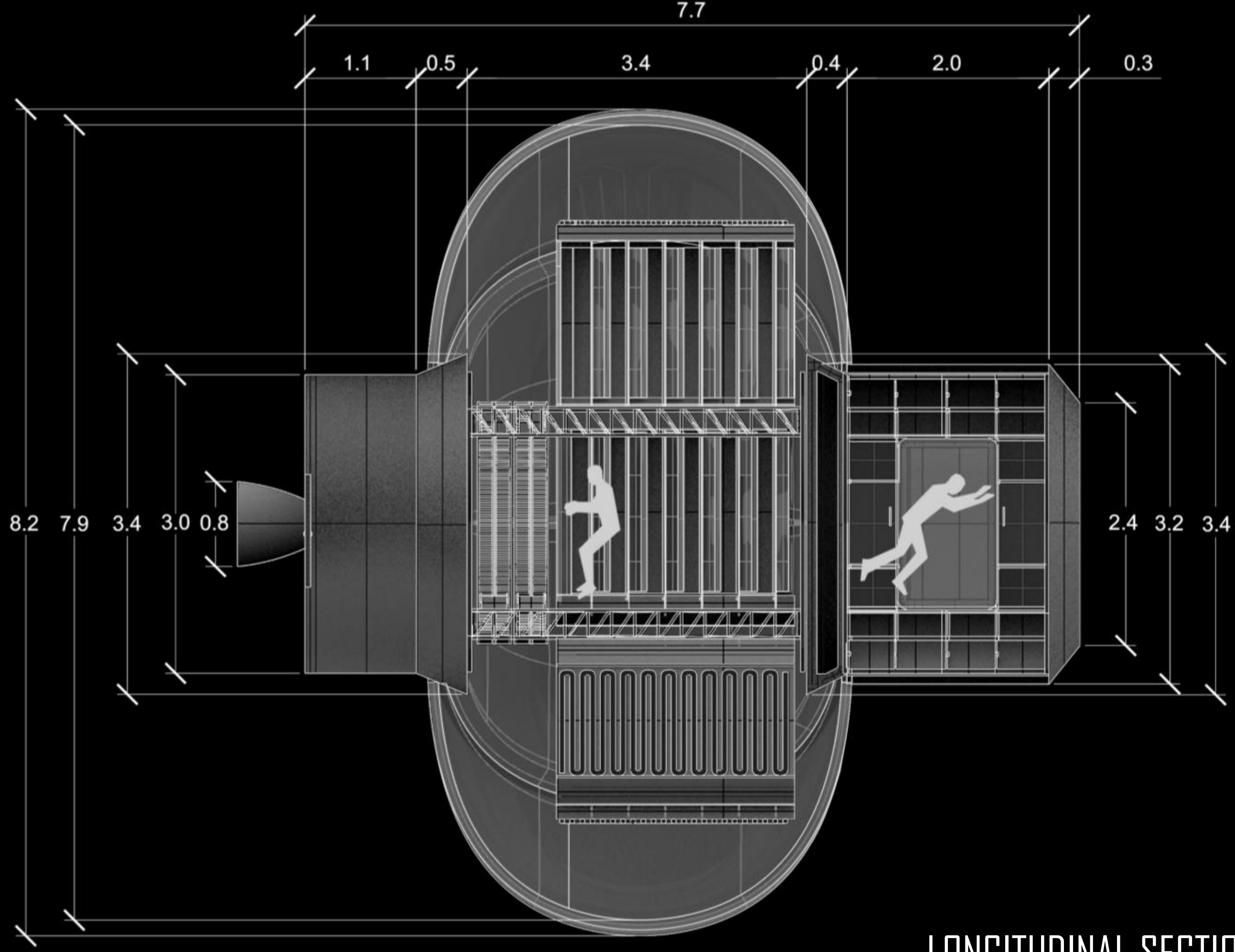
MELiSSA FOUNDATION

INTERNAL CONFIGURATION

After being launched and parked in Earth orbit, the module would deploy the PV panels and inflate autonomously, with the four racks folded in stowed position.

Internal pressure would be equalized and systems for lighting, water feeding, and recovery activated.

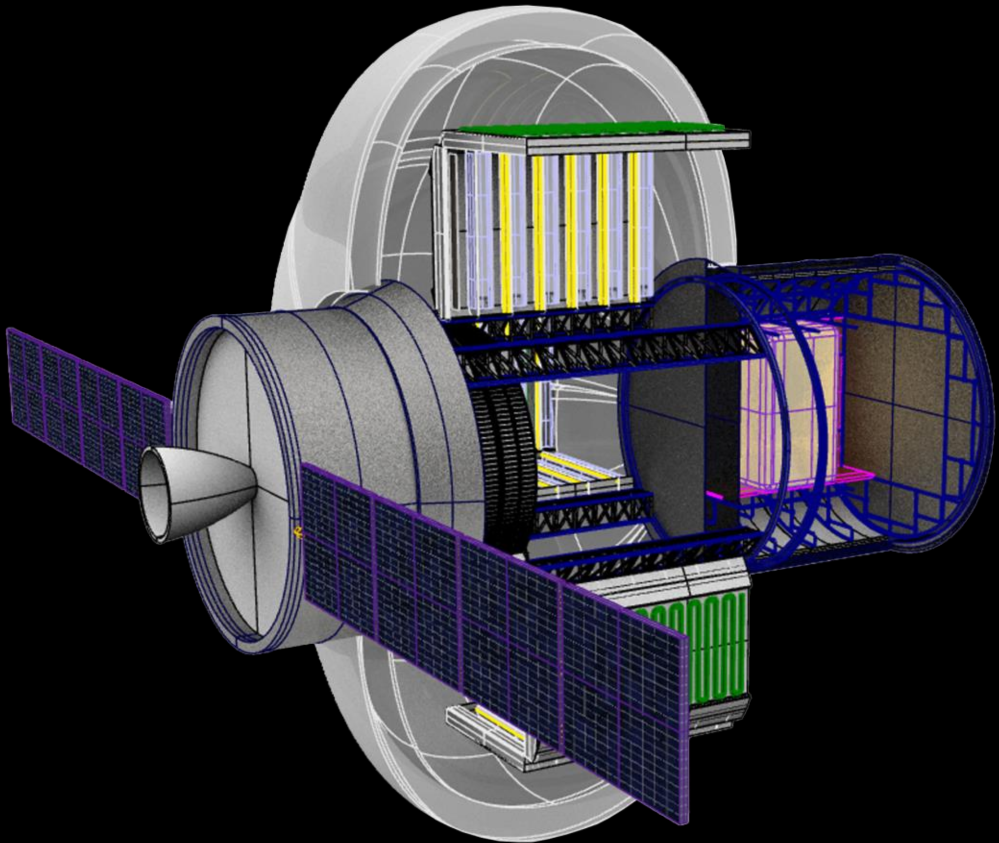
The final internal configuration would require a minimal intervention from the crew onboard in securing the racks in open position and complete the operational setting of systems.

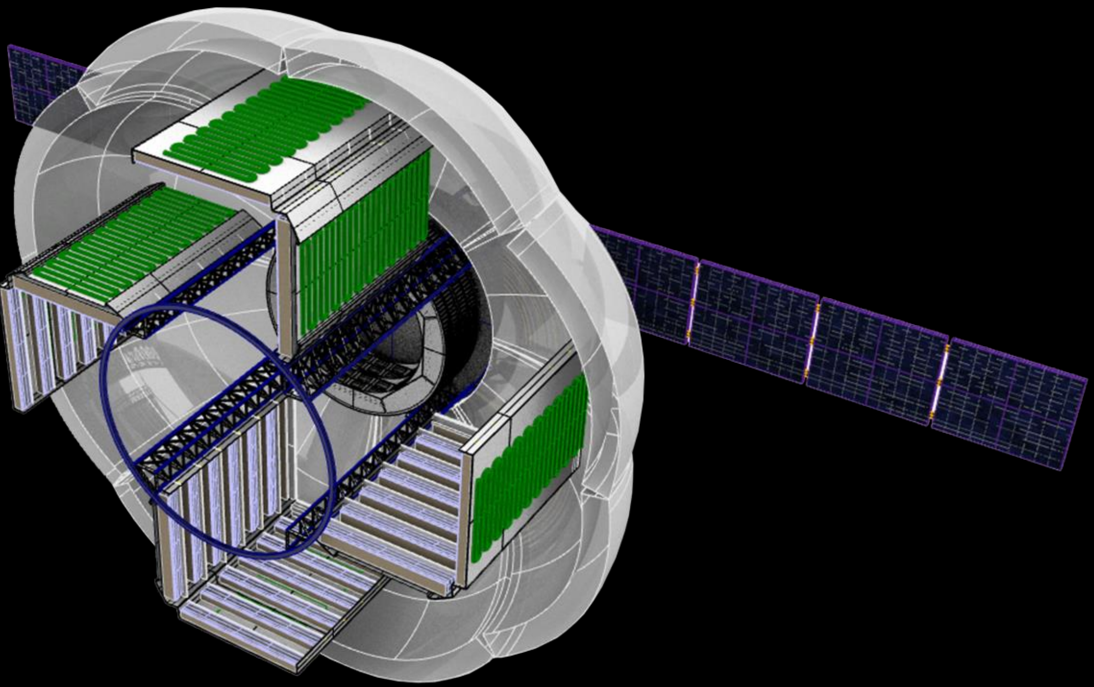


LONGITUDINAL SECTION.

MELiSSA FOUNDATION

INTERNAL CONFIGURATION





CUTAWAY 3D SECTIONS.

MELiSSA FOUNDATION

1. STRUCTURAL STANDOFF

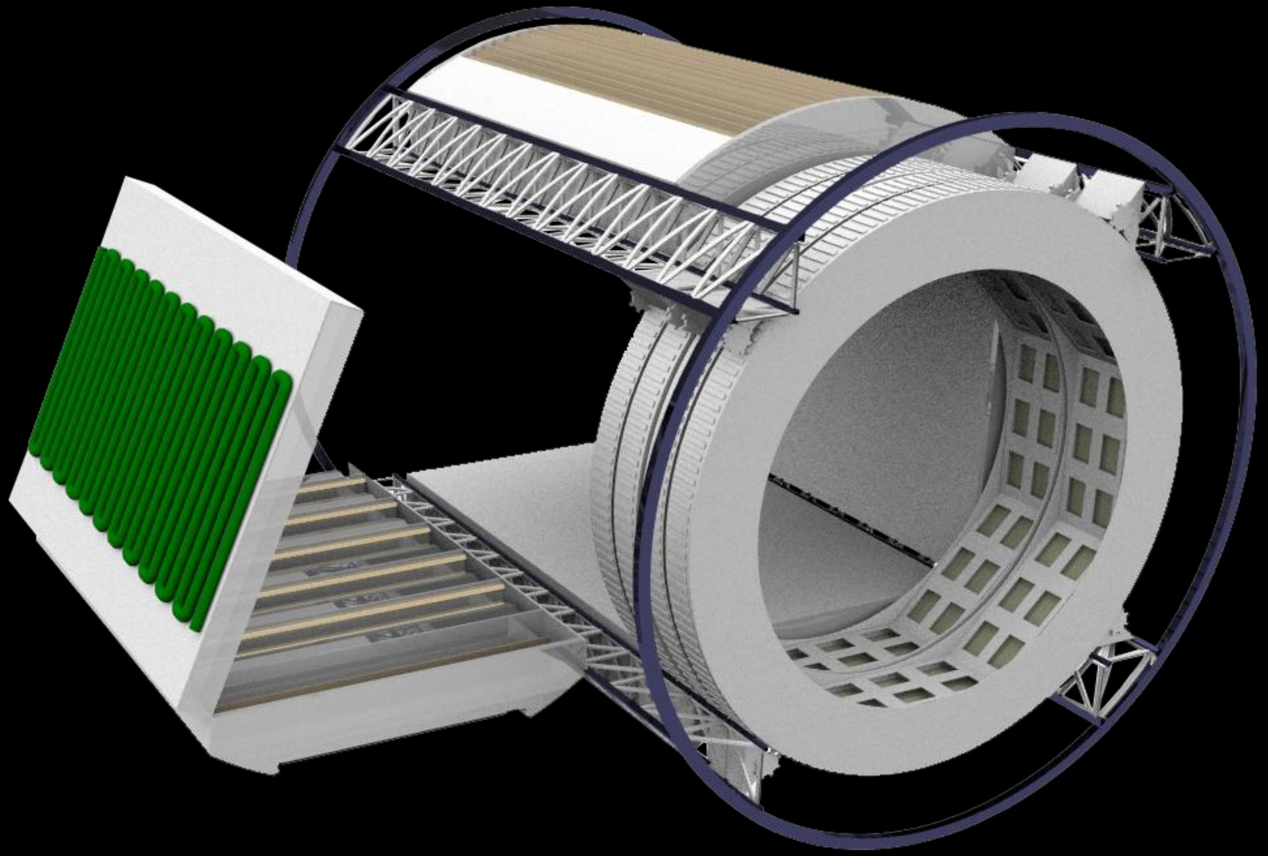
THESE STRUCTURAL PARTS SUPPORT THE DISTRIBUTION OF VARIOUS UTILITIES:

Structurally connecting the end cone of the SM to the rigid forward section of the module, which is hosting the BLSS systems and the main hardware,

THESE STANDOFFS HAVE THE MULTIPLE FUNCTION OF

a. Structural girders,
b. Utilities connectors,
c. Support for additional lighting system, and
d. Hinged points for the four folded racks rotating outward the central aisle once the shell is inflated.

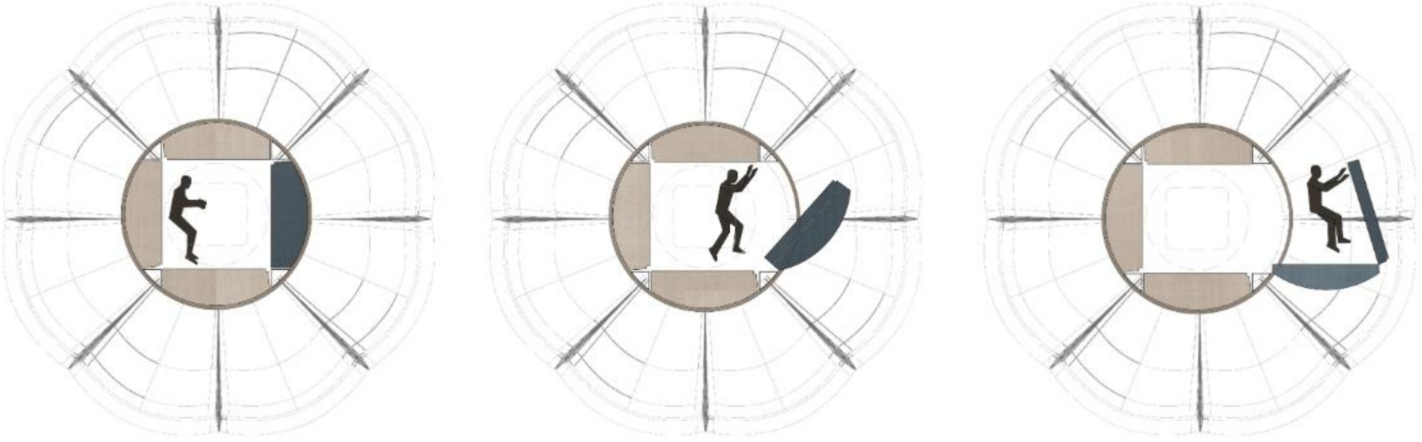
Due their double function as structural elements and utility connectors, they are dimensioned to withstand torsional and sheer forces during launch and autonomous propulsion phases



MELiSSA FOUNDATION

2. RACKS

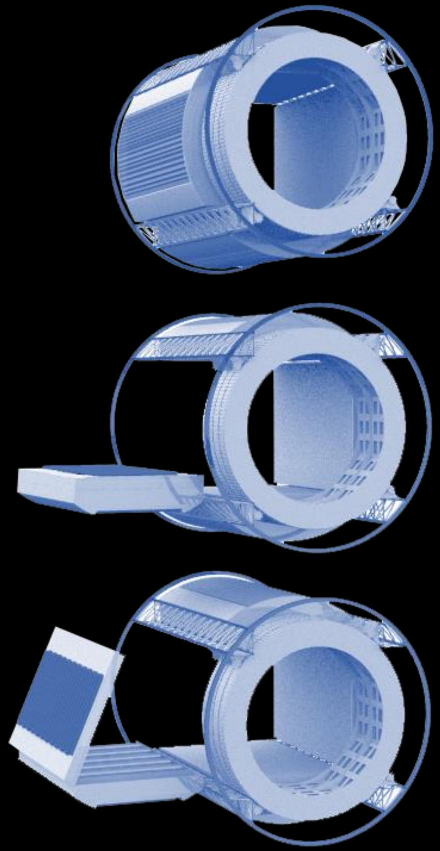
FOLDABLE RACKS COMPONENTS



DIANGRAM SHOWING THE FOLDABLE RACKS IN ENCLOSED WITHIN THE STANDOFF

FIRST UNFOLD OF THE RACKS

SECOND UNFOLD OF THE RACKS



RACKS CLOSED

RACKS OPEN

RACKS UNFOLD

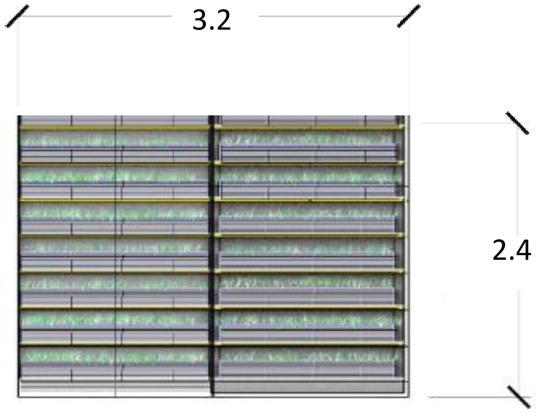
2. RACKS

FOLDABLE RACKS COMPONENTS

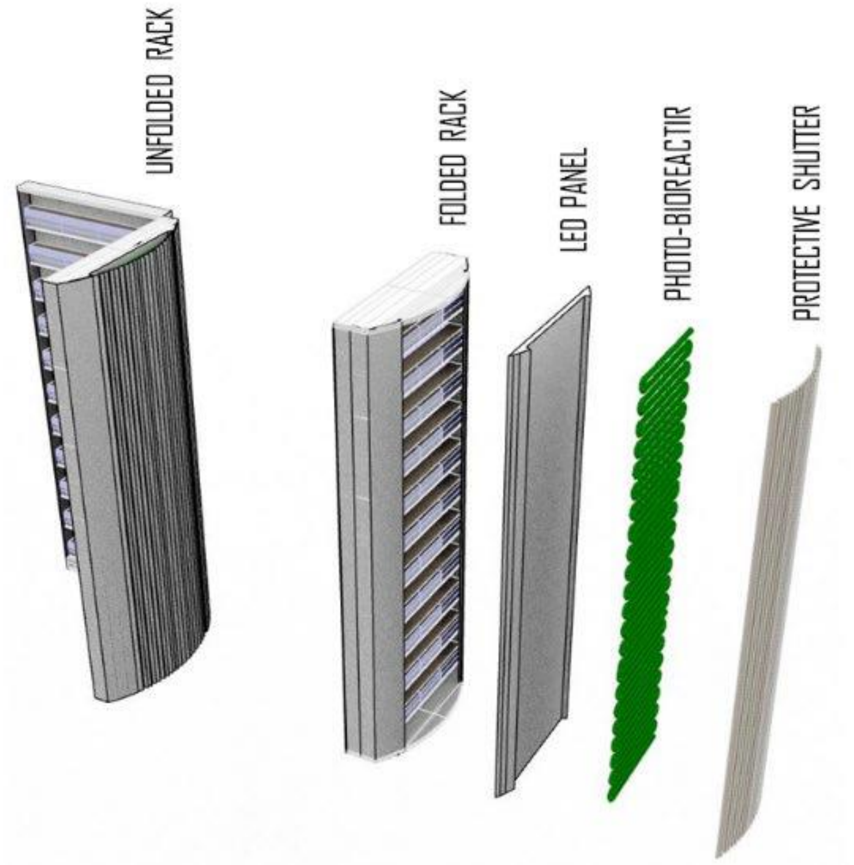
In this study the module is configured as greenhouse and BLSS lab, with racks designed to host two photo-bioreactors for microalgae on the external sides, and aeroponic shelves in the internal sides.

During the launch phase in stowed position, racks are sealed and pressurized at low pressure, both plants and bioreactors are padded with plants' shelves normal to vertical axis.

Bioreactors on external sides are protected by shutters to prevent damage during the folding and compressing phase of the shell at ground,



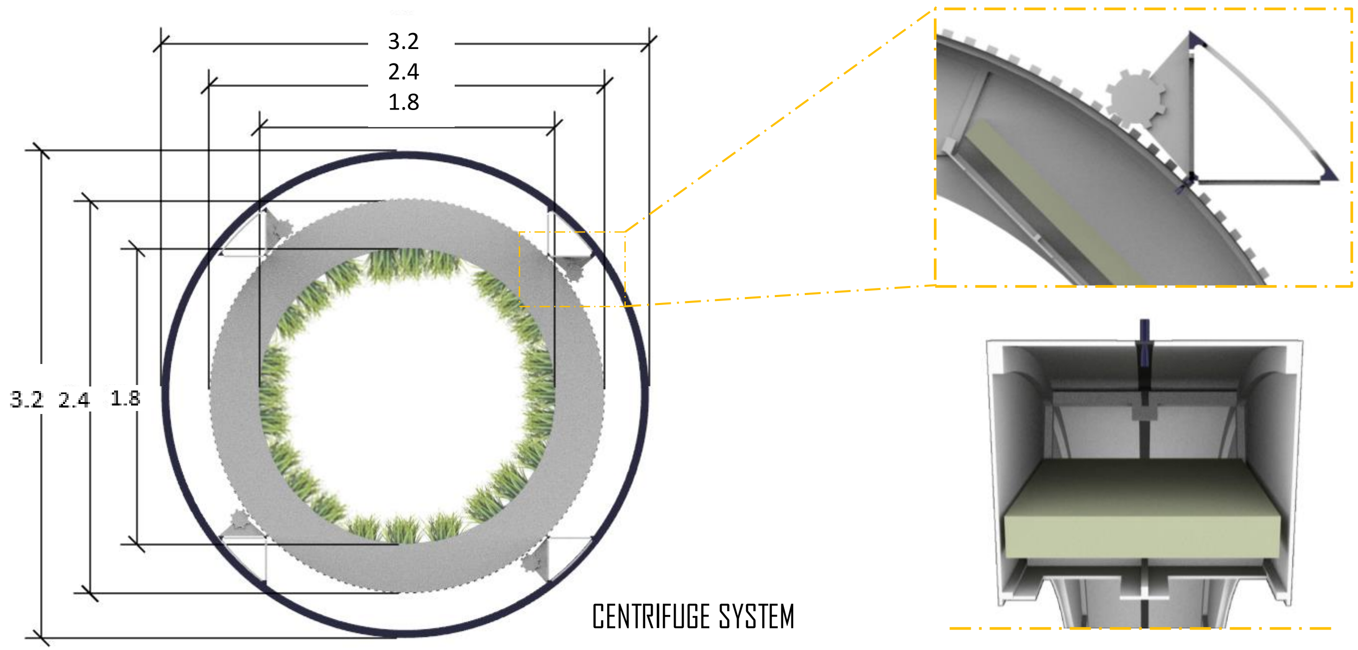
AREA OF THE RACKS FULLY EXPOSED WITH THE AEROPONIC SYSTEM

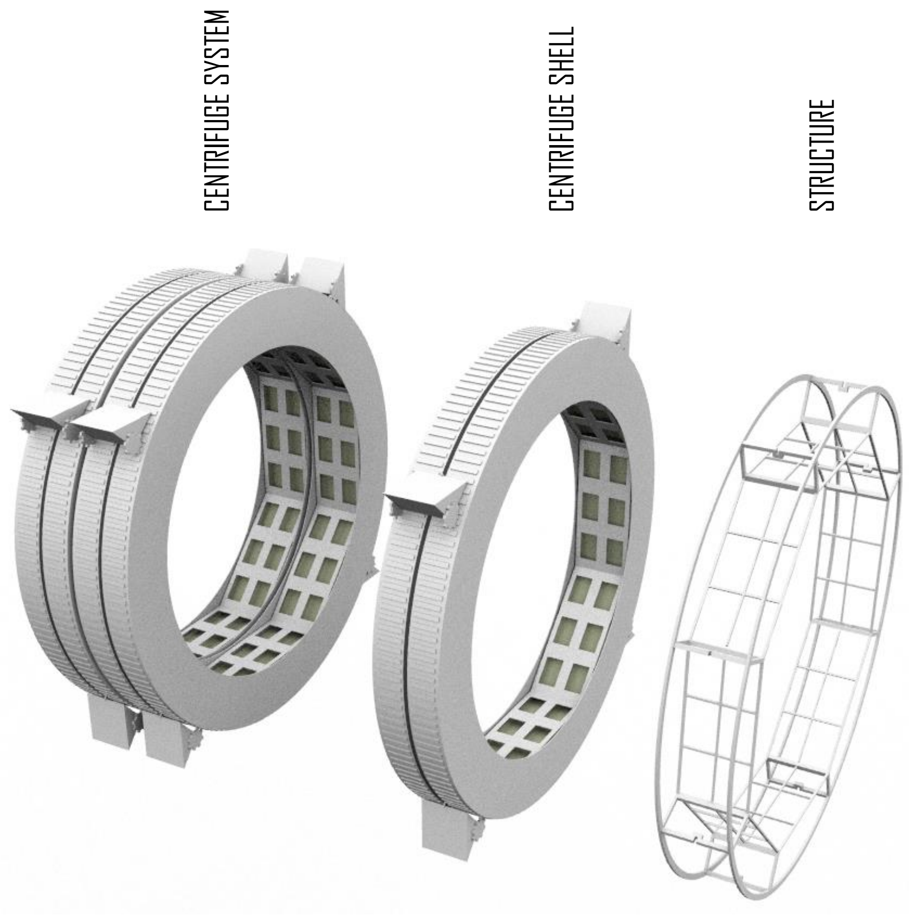


CENTRIFUGE COMPONENTS

2. CENTRIFUGE

The inflatable section presented here has been furtherly improved with two centrifuges for plants, These two centrifuges of 2.4 m of diameter are counter-rotating at low rpm to balance the gyroscopic effect, and simulate a reduced gravity between 0.05 and 0.1 g. The centrifuges are configured as rotating racks with autonomous water and nutrients feeding to test roots behaviors.





3. BLSS SYSTEMS

The proposed BLSS of the module is connected to the ECLSS of the station and arranged into four treatment compartments using biological processes like the loop scheme experimented in MELiSSA project

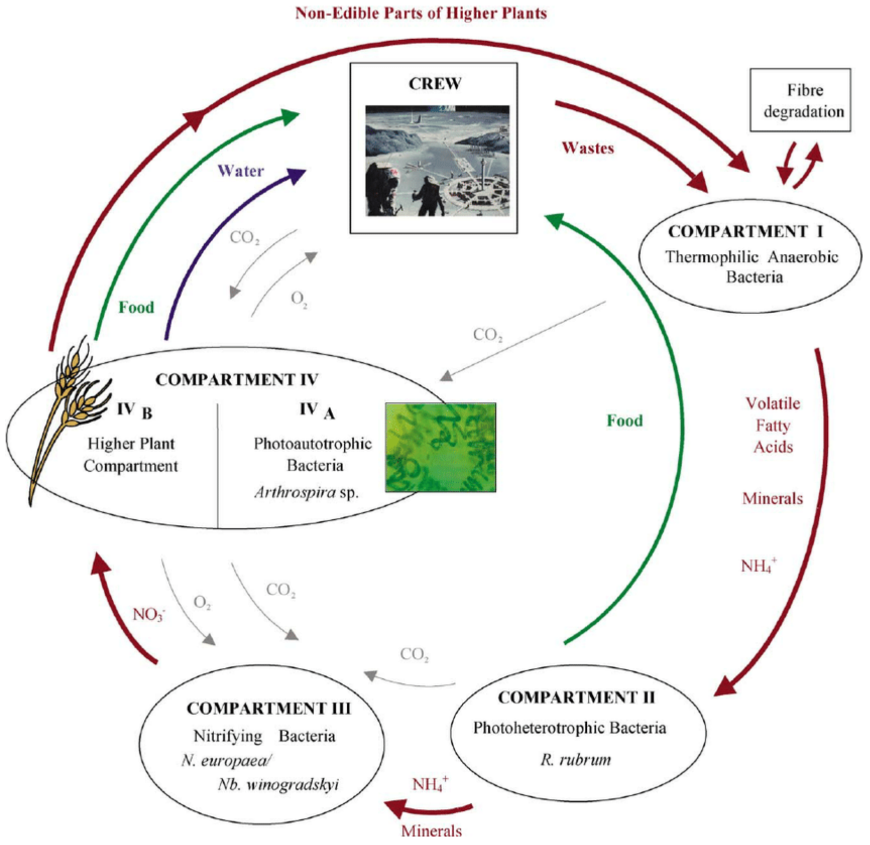
COMPARTMENT I	Plants and Human Waste Treatment (thermophilic anaerobic digestion)
COMPARTMENT II	Low Molecular Carbon-compounds Treatment (volatile fatty acid, CO2, H2, and H2S)
COMPARTMENT III	Nitrifying Treatment (NH4 and minerals)
COMPARTMENT IV A	Higher Plants
COMPARTMENT IV B	Photoautotrophic Bacteria (Arthrospira Platensis Spirulina)

USABLE VOLUME FOR INSTALLATIONS:

Rigid Racks Volume= 4.7m3

Foldable Racks Volume= 7.7m3

Centrifuge Volume= 2.62m3



(Image by Hendrickx et al)

3. BLSS SYSTEMS

THE FORWARD RIGID SECTION:

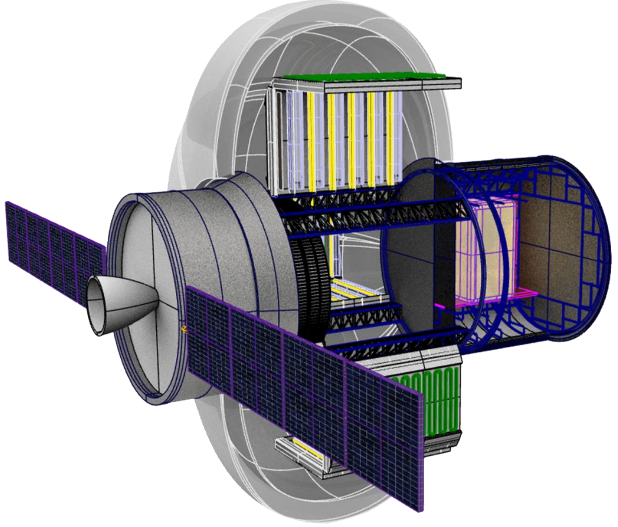
The forward rigid section of the module is equipped with two hatches and constantly pressurized during launch phase.

The hatch with the inflatable section acts as emergency closing in case of pressure loss.

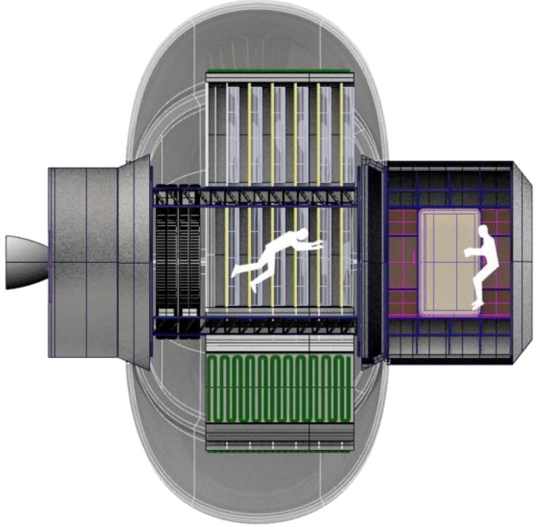
Racks are placed on sides and deck, leaving the ceiling partially free for hatches' closing mechanisms.

These racks host the BLSS hardware and are fully accessible for maintenance from the central aisle, an extensible toilet for the crew is placed on one side.

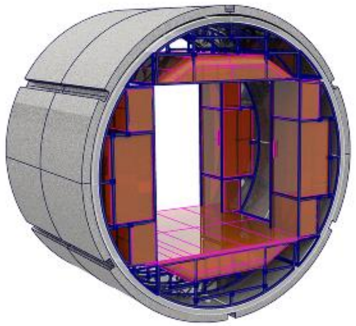
The toilet is an integral part of the BLSS, since it collects the human waste and wastewater necessary to activate the anaerobic digester and source of carbon and nitrogen as nutrients for the plants.

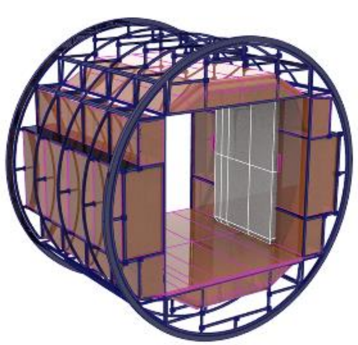


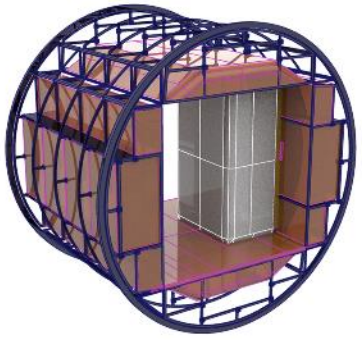
LONGITUDINAL SECTION WITH FOLDABLE RACKS OPEN



TRANSVERSE SECTION PERSPECTIVE SHOWING THE TEST FACILITY





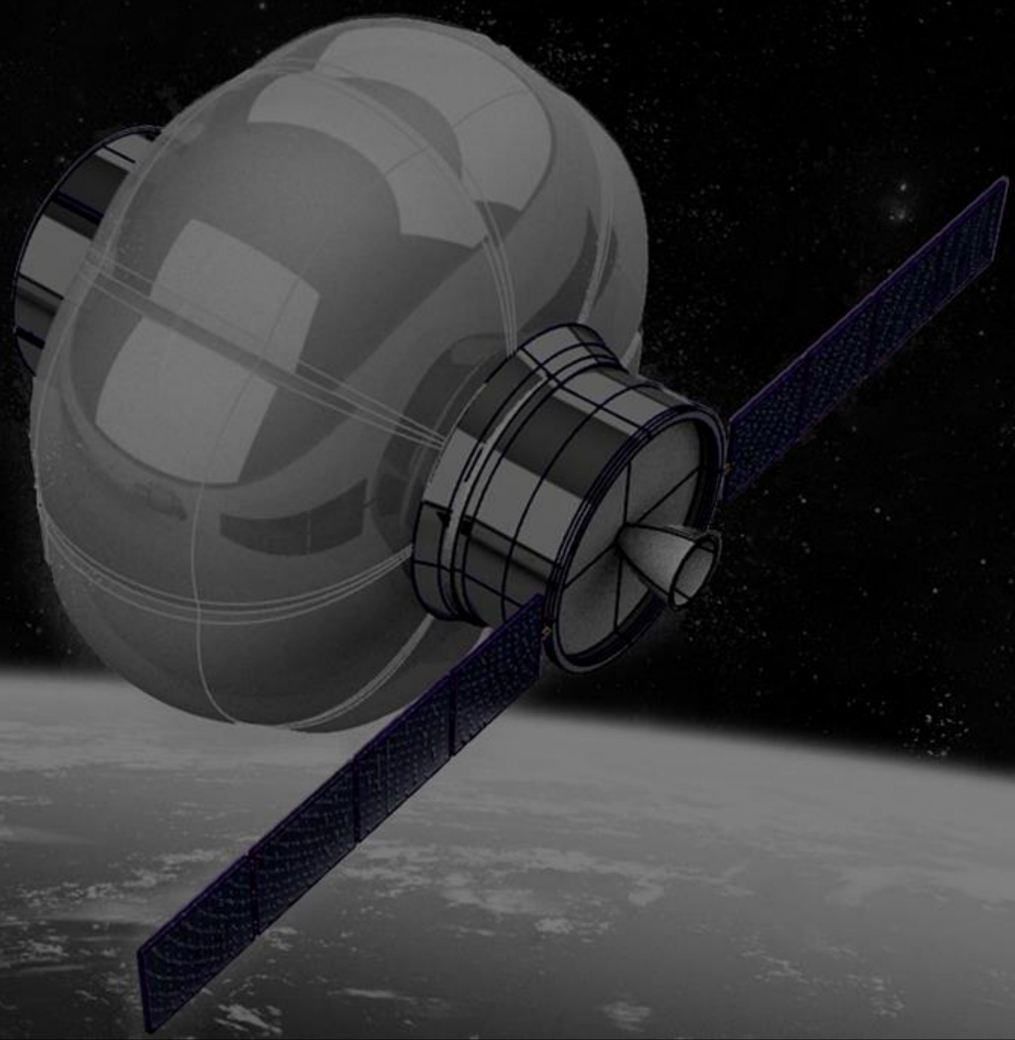


CONCLUSIONS

The concept study presented here is an evolution of the initial concept presented at the ICES 2022 in Saint Paul MN and based on design of a minimal configuration module for testing and experimentation of closed loop bioregenerative life support systems, using MELiSSA as proof-of-concept. On this purpose, this concept study proposes a dedicated BLSS module as test bed for research and experimentation of bioregenerative systems in permanent microgravity conditions,

It is supposed that the knowledge and experience accrued during the experimental and operational phases in orbital facilities could be easily integrated into future DSTVs, or scaled up into larger facilities and different configurations, like habitats on planetary surfaces.

Furthermore, it would represent a powerful driver for the development of a closed-loop technology with the highest level of reliability, particularly in terms of potential bio-contamination in case of failures.



THANK YOU.

Paolo Caratelli
Abu Dhabi University

paolo.caratelli@adu.ac.ae

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