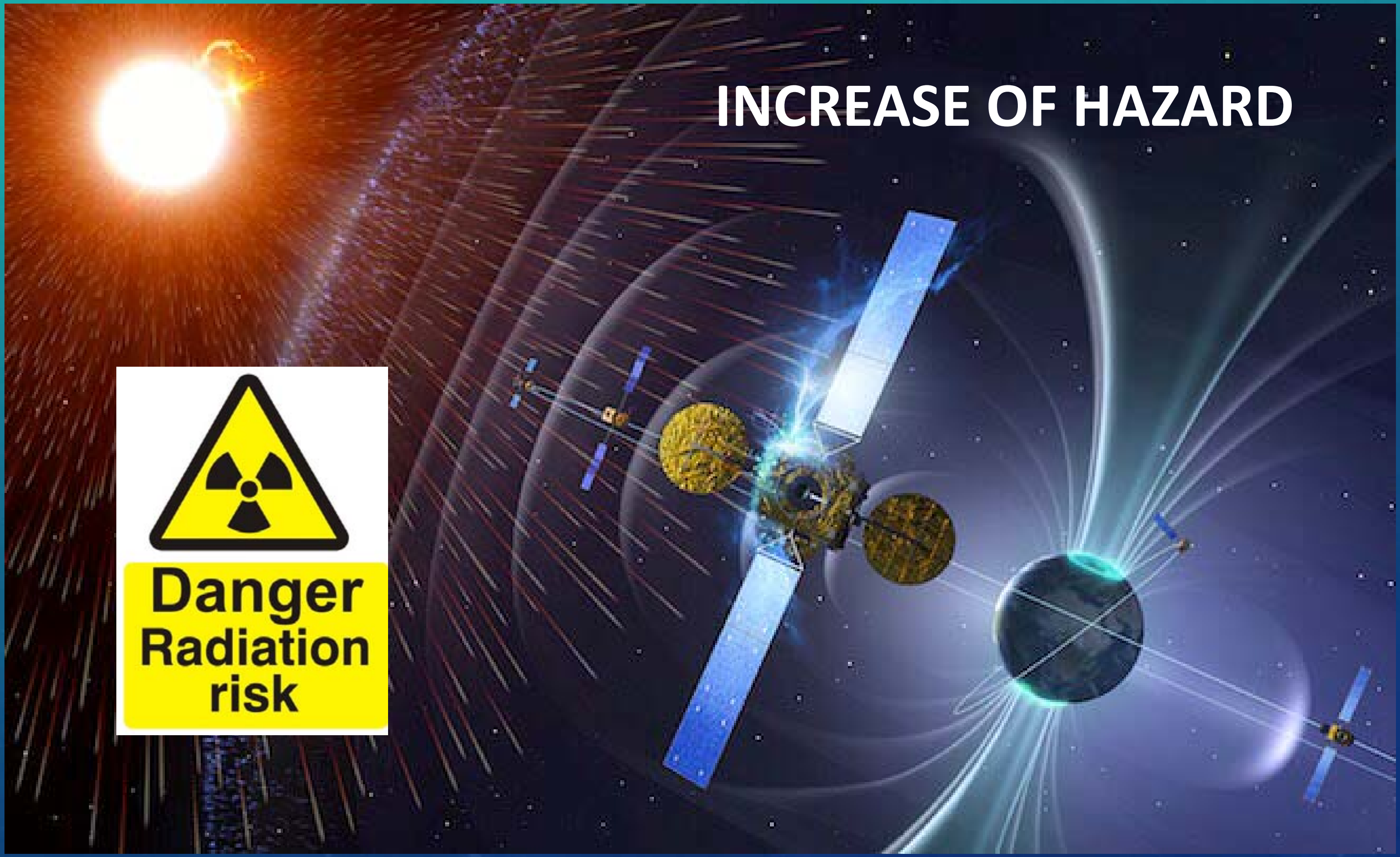
CubeSat Cultivation System for the growth of a fortified «Micro-Tom»

Authors: Giulio Metelli, Eugenio Benvenuto, Luca Nardi, Giuseppe Zummo, Chiara Burattini, Fabio Santoni, Fabio Bisegna, Ivan Masfiq Ahmed, Paolo Marzioli, Luca Gugliermetti

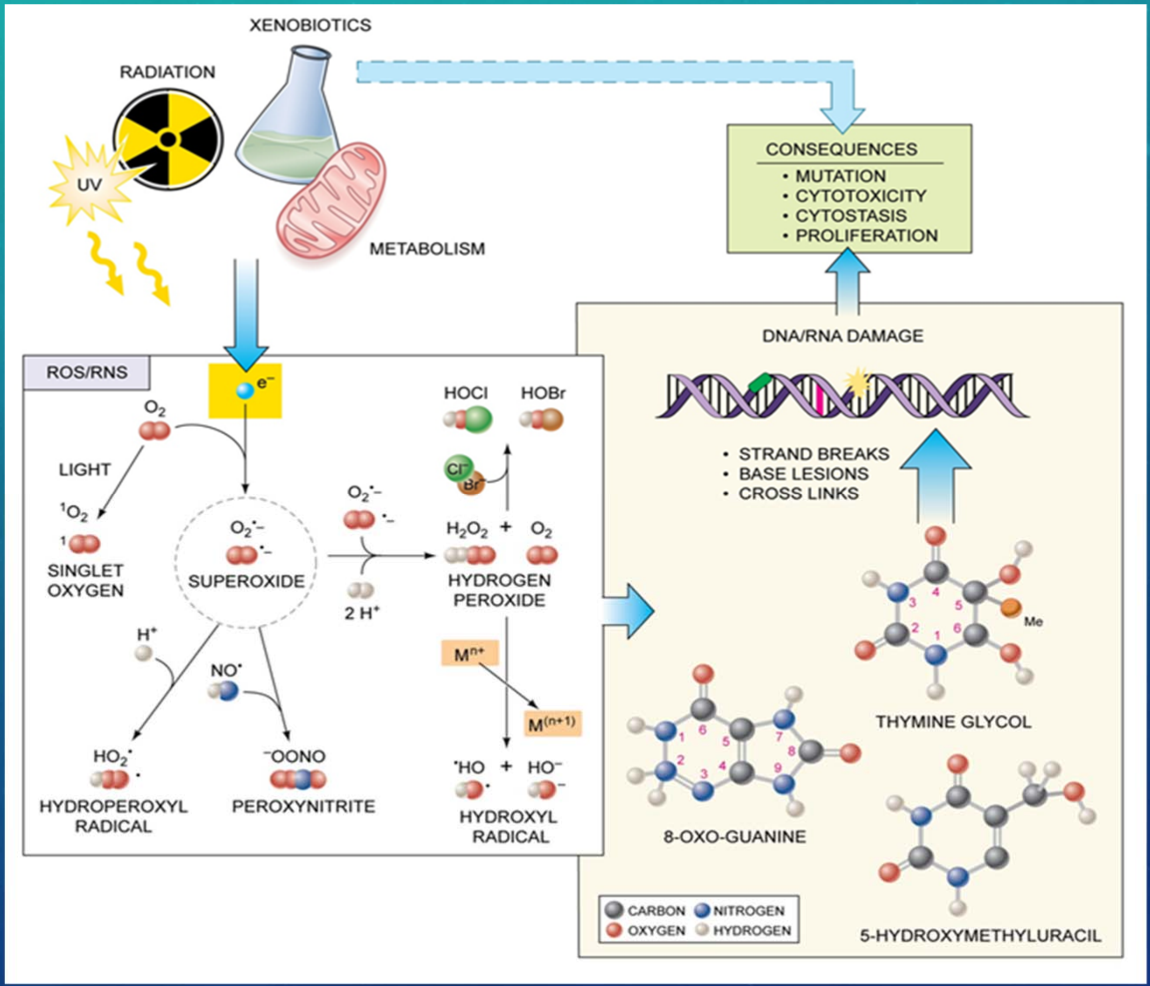
Presenter: Paolo Marzioli, Sapienza – University of Rome

1st AgroSpace – MELiSSA Workshop
16 – 18 May 2018
Italian National Research Council (CNR), Rome, Italy

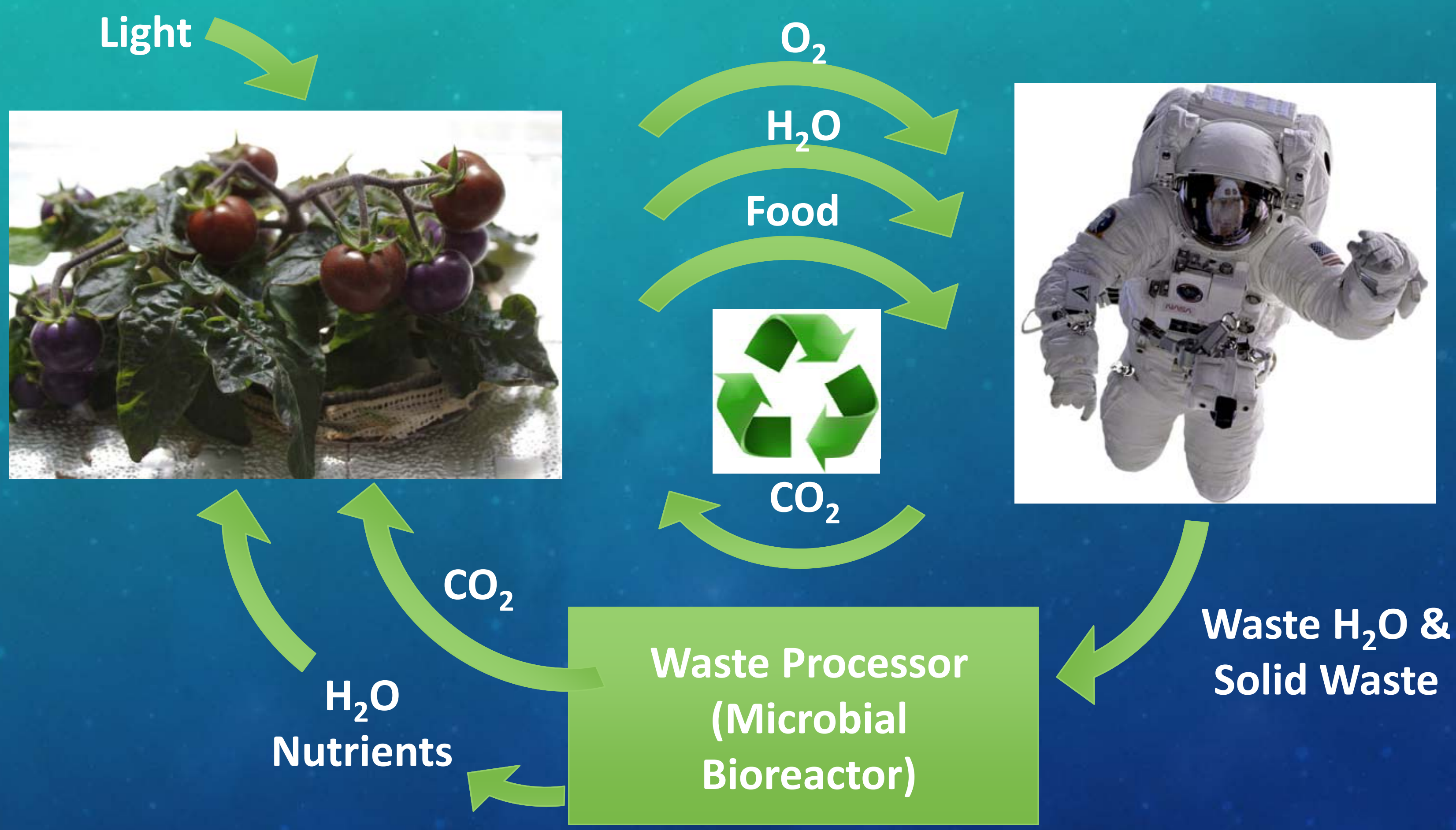
MICROGRAVITY AND RADIATIONS IN SPACE



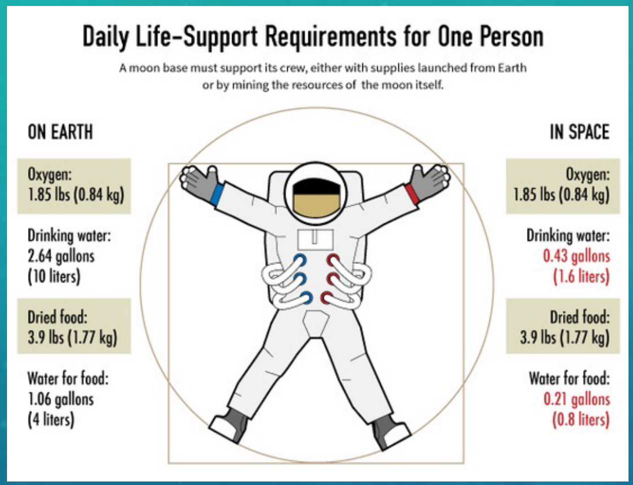
ROS AND DNA DAMAGE



PLANTS IN SPACE A KEY FACTOR IN BIOREGENERATIVE SYSTEM



FOOD IN SPACE



Astronaut daily meal

"Outredgeous" red romaine lettuce harvested from Veggie plant growth system on International Space Station
Credits: NASA

Lyophilized **vs** **Fresh**

BIOXTREME PROJECT

PLANT IDEOTYPE → FOR SPACE

In broad sense an Ideotype model which is expected to perform or behave in a predictable manner within a defined environment.

Euphytica 17 (1968): 385–403

THE BREEDING OF CROP IDEOTYPES

C. M. DONALD

Waite Agricultural Research Institute,
The University of Adelaide, South Australia

Received 17 November, 1967

- Development of conceptual theoretical model
- Selection of base material
- Incorporation of desirable characters into single genotype
- Selection of ideal or model plant type

MICRO-TOM WILD TYPE

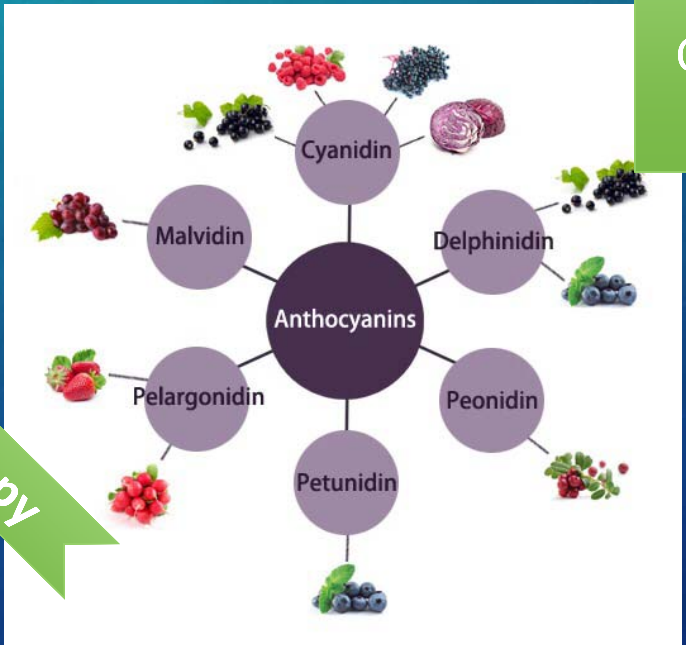
Scott, J.W. and B.K. Harbaugh 1989 Micro-Tom, a miniature dwarf tomato.
Florida Agr. Exit. Sta. Circ S-370

- Micro Tom a model cultivar for tomato research
- Small size (15-20 cm)
- Short life cycle (seed-seed 70-90 days)
- Able to grow under fluorescent light
- Easy to cultivate
- High photosynthetic efficiency
- High productivity (20-30 fruits/plant; 2-5 gr/fruit; mean diameter of fruits 15 mm)
- Continuous flowering
- Can be grown at high density (≥ 100 plant/m^2)
- Better performances in hydroponics

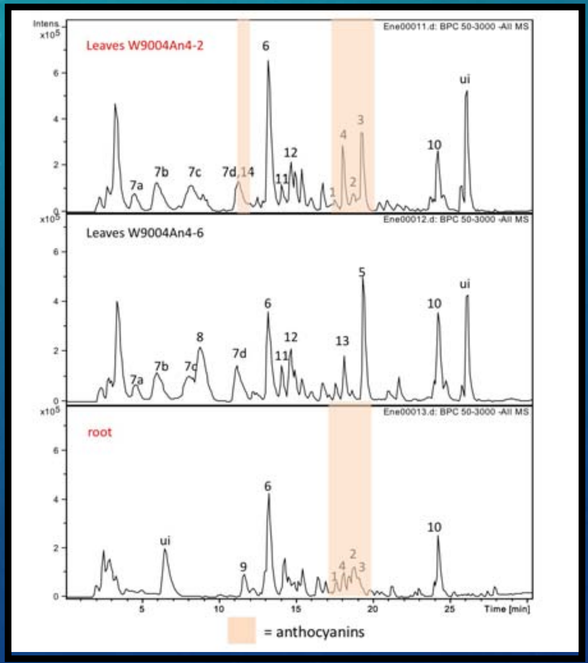
BENEFICIAL EFFECTS OF ANTHOCYANINS THERAPY ON HUMAN HEALTH

Adverse conditions → Oxidative stress → Oxidation of vital molecules → Development of disease → Aging, Cancer, Hypertension, Cardiovascular disease, Asthma, Infections

Antioxidant therapy



MICRO-TOM TAILORED FOR SPACE



1 delphinidin

2-4 petunidin

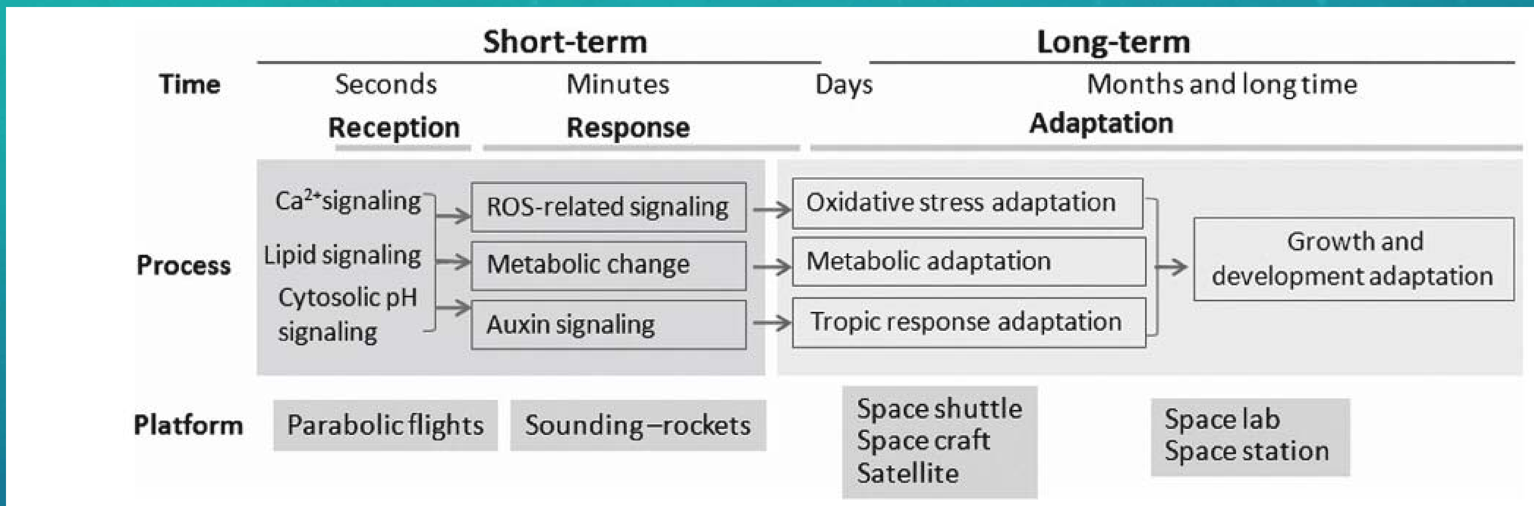
SIMULATED MICROGRAVITY

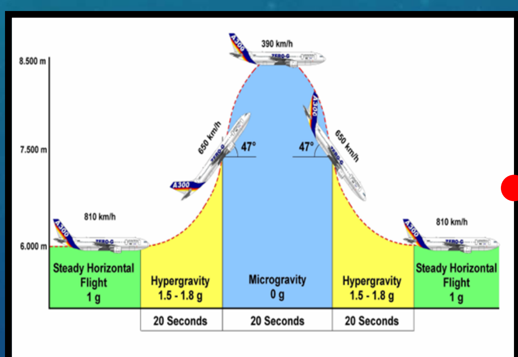
LED LIGHT

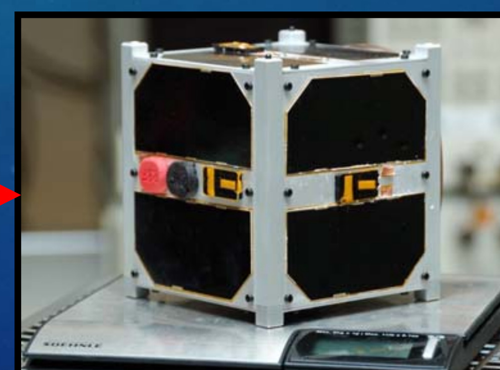
UNIAXIAL CLINOSTAT

MICROTOM IN GROWTH VESSEL

REAL MICROGRAVITY EFFECTS ON PLANTS







MICRO-TOMATO GROWTH ON CUBESATS – OUR MISSION

AIR PRESSURE CONTROL

AIR O2/CO2 PERCENTAGE CONTROL

WATER/NUTRIENTS MANAGEMENT

LIGHT

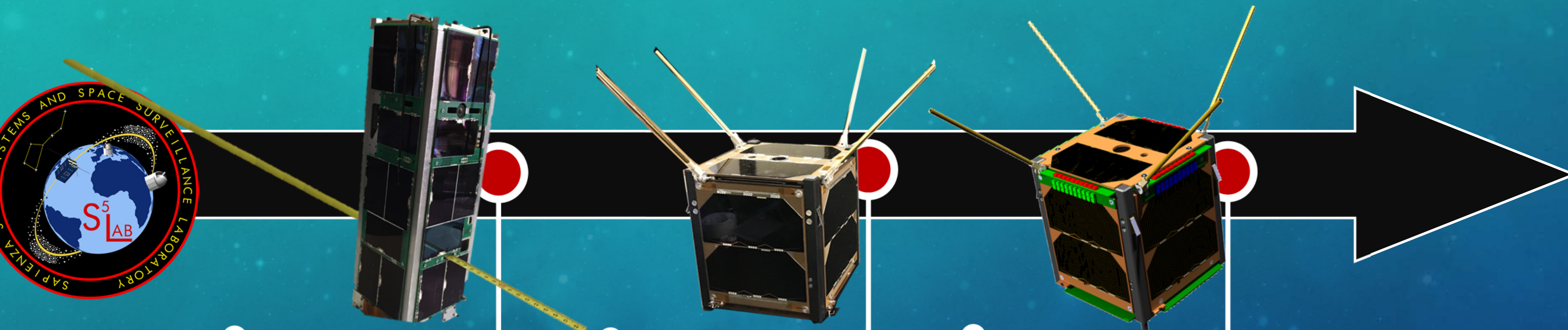
DAY/NIGHT CYCLES CONTROL

TEMPERATURE CONTROL

PLANT VITAL PARAMETERS MONITORING

The described functions are compatible with the Micro-Tomato plants on a 12U Cubesat

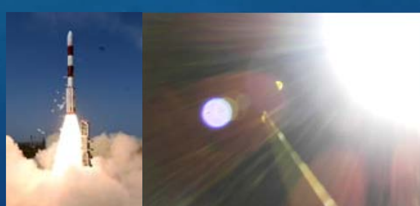
S5LAB – CUBESAT DEVELOPMENT TIMELINE



URSA MAIOR

University of Rome La Sapienza Micro-Attitude In-Orbit Testing

2014 – In orbit
Status: Launched on 23 June 2017



1KUNS-PF

1st Kenyan University Nano-Satellite – Precursor Flight

2017 – Ready for deployment from ISS
Status: Launched to ISS on April 2, 2018

LEDSAT

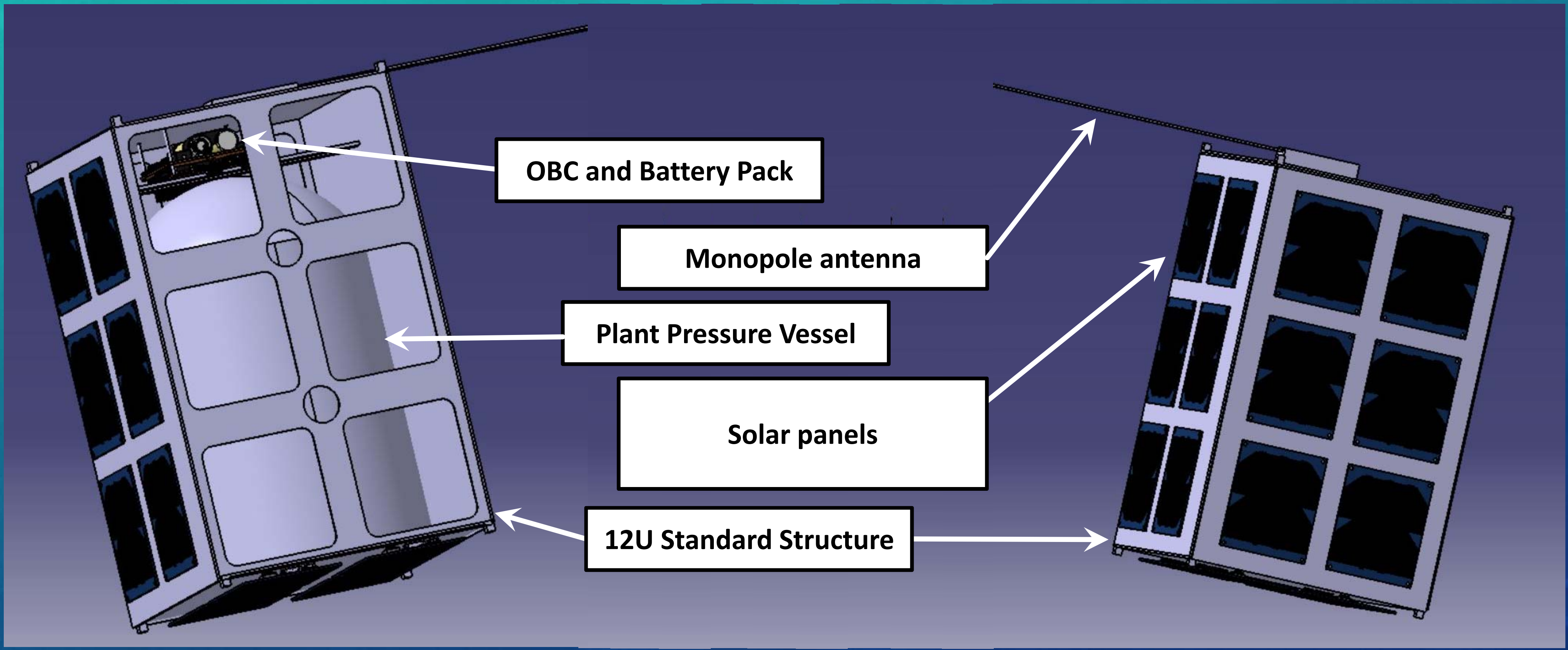
LED-based small SATellite

2017 – Under development
Status: To be launched in 2019

AVAILABLE FACILITIES AT DIAEE SAPIENZA

Low- and High-Vacuum chambers suitable for testing the micro-tom plants in hypobaric environment

12U CUBESAT OUTLINE



SATELLITE DESIGN

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

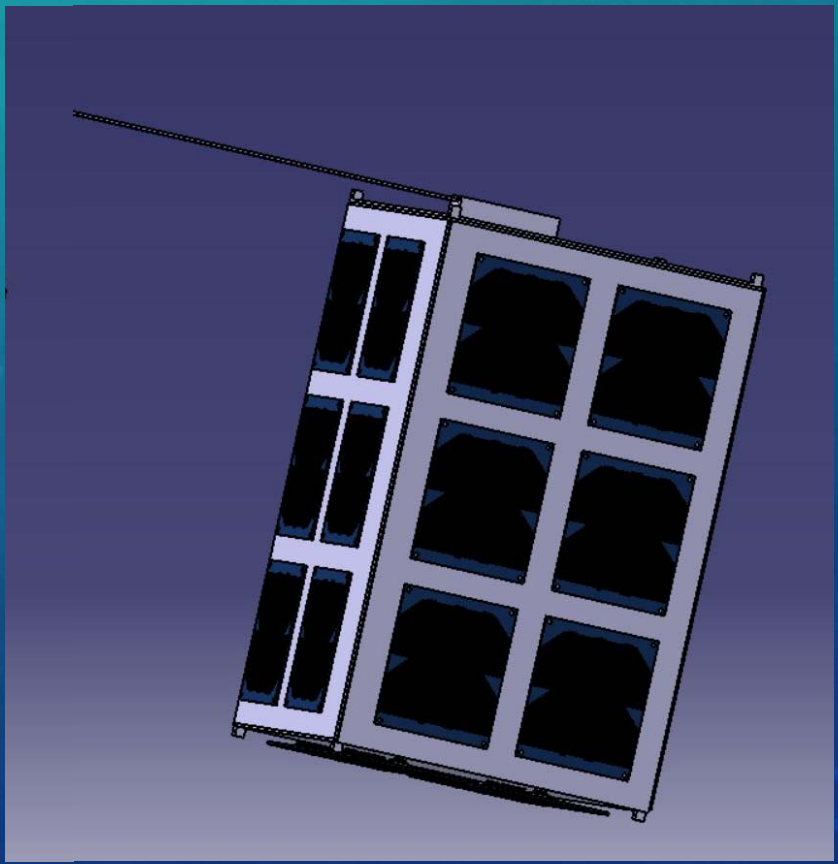
ON-BOARD DATA HANDLING

ELECTRIC POWER SUBSYSTEM

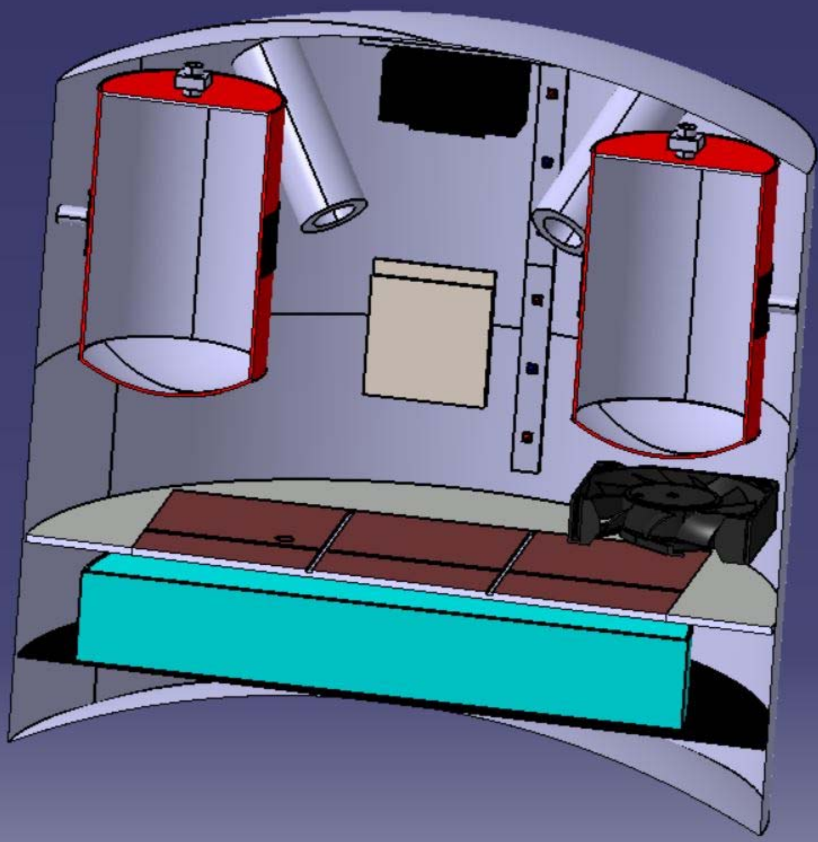
TELEMETRY, TRACKING AND CONTROL

ATTITUDE DETERMINATION AND CONTROL SUBSYSTEM

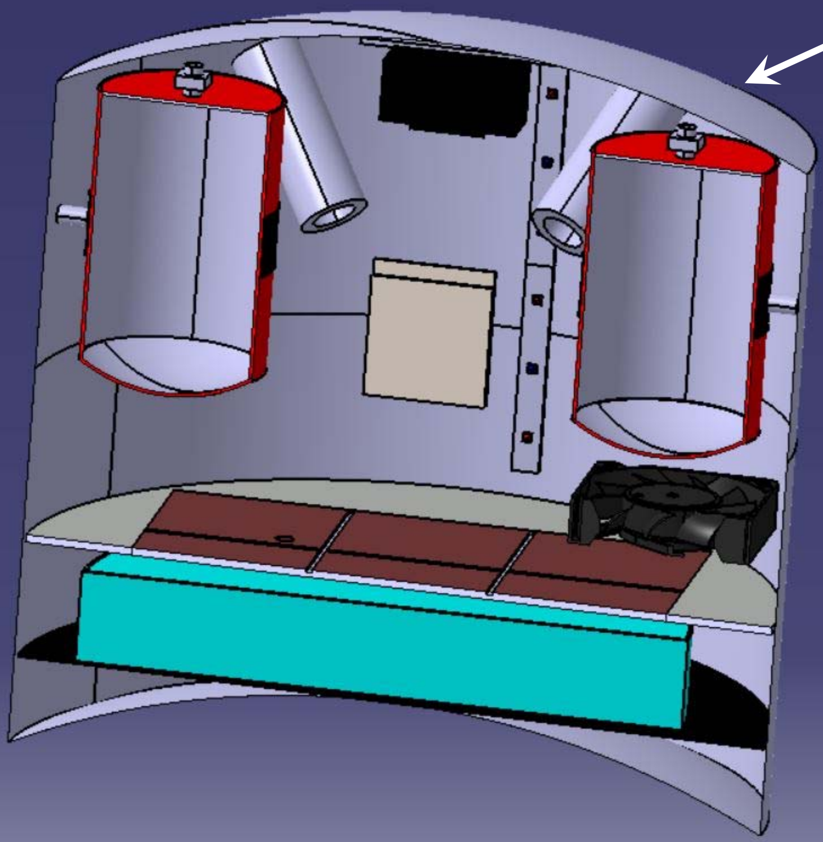
ACTIVE THERMAL CONTROL SUBSYSTEM



PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



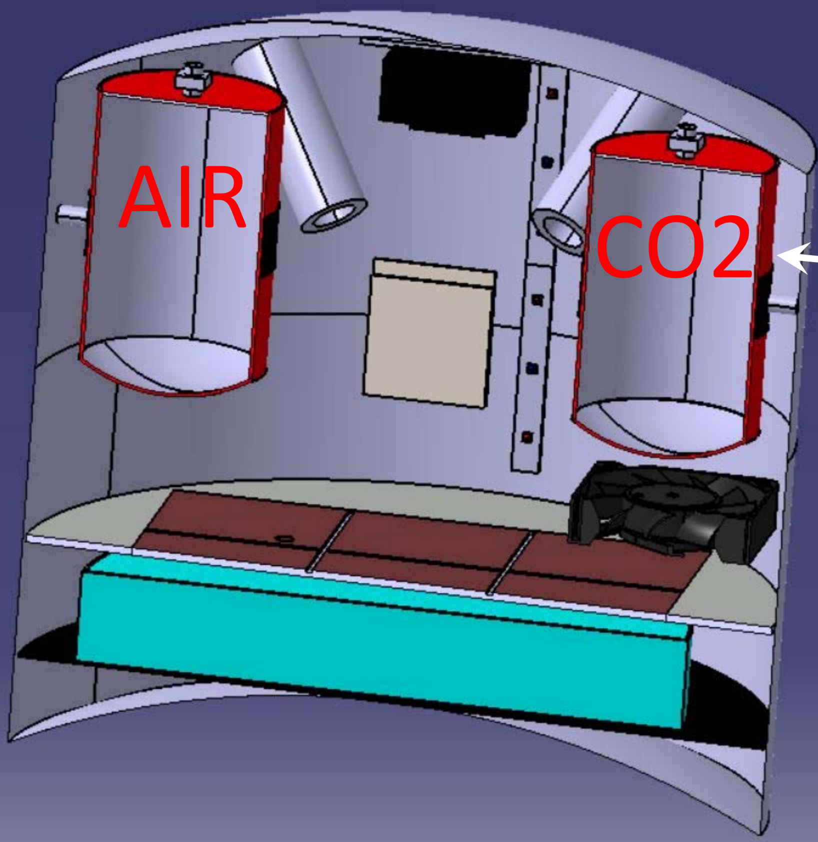
PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



25 cm diameter – fits with 12U standard

Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



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Pressurized at 25 kPa (0.25 atm) –
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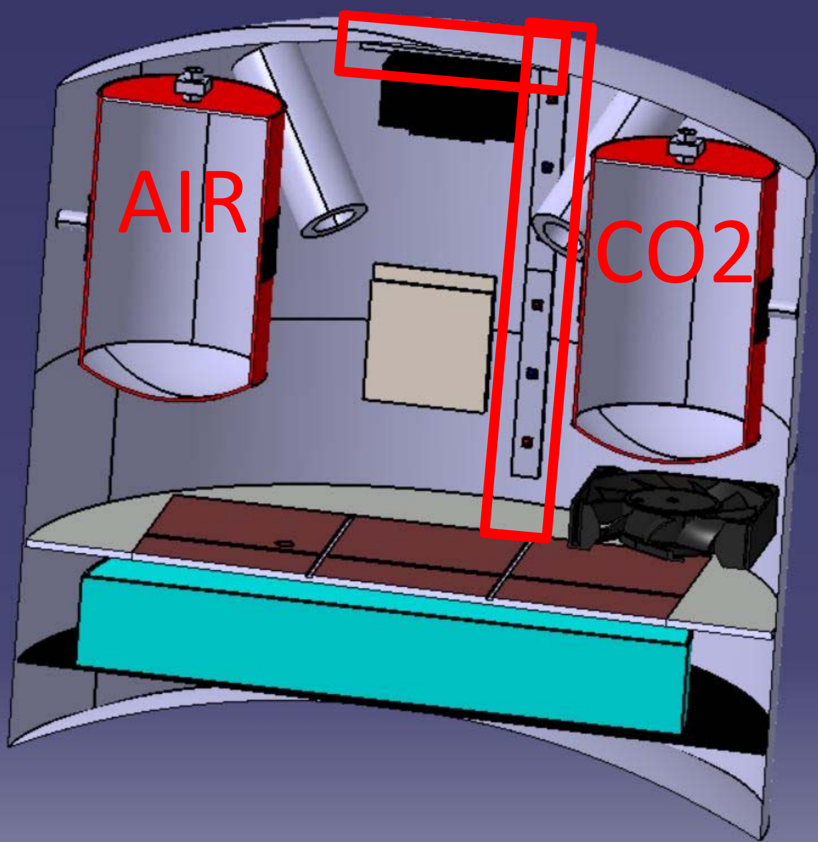
Gas tanks: Air and CO2

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



25 cm diameter – fits with 12U standard

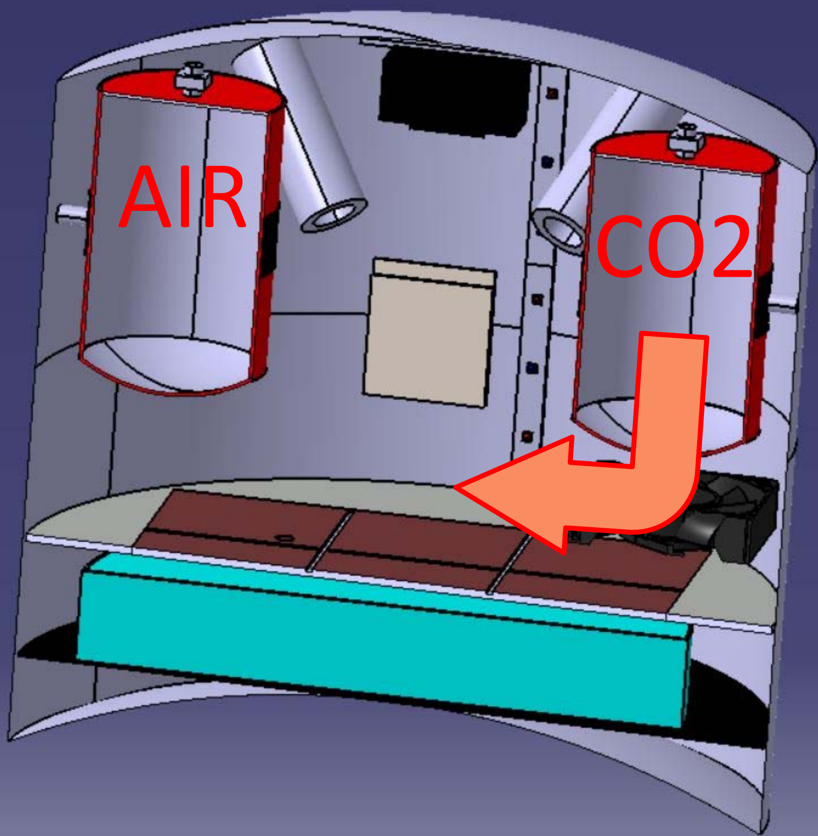
Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

Gas tanks: Air and CO2

LED arrays

- Top
- Vertical Bars

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



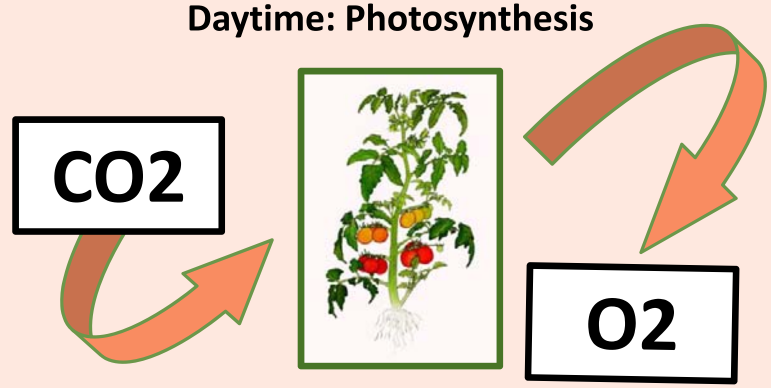
25 cm diameter – fits with 12U standard

Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

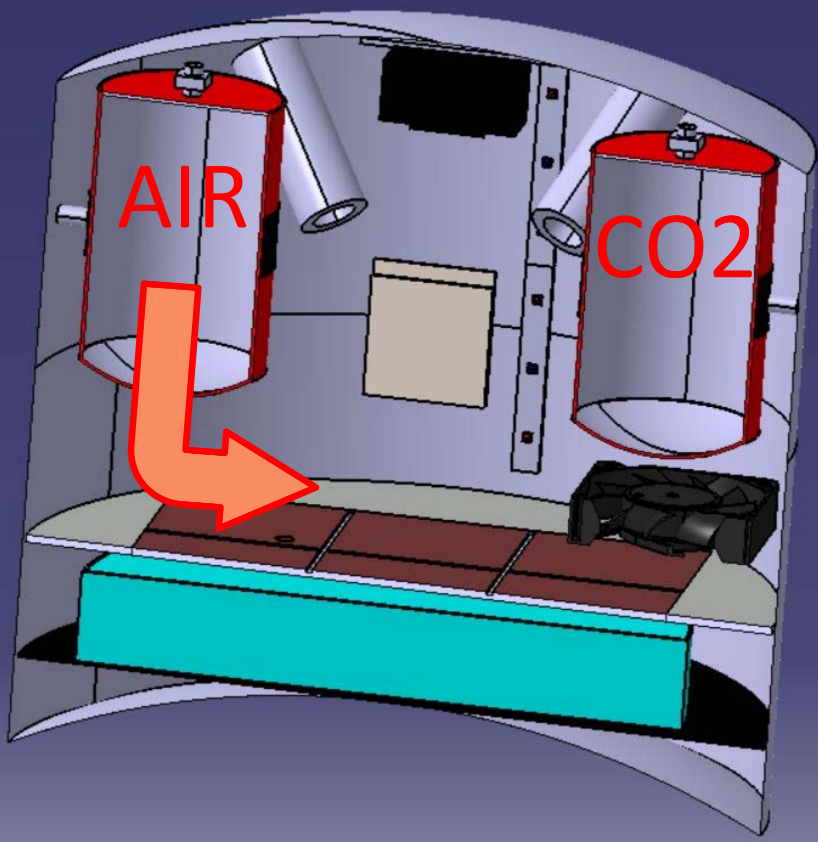
Gas tanks: Air and CO2

LED arrays

Daytime: Photosynthesis



PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



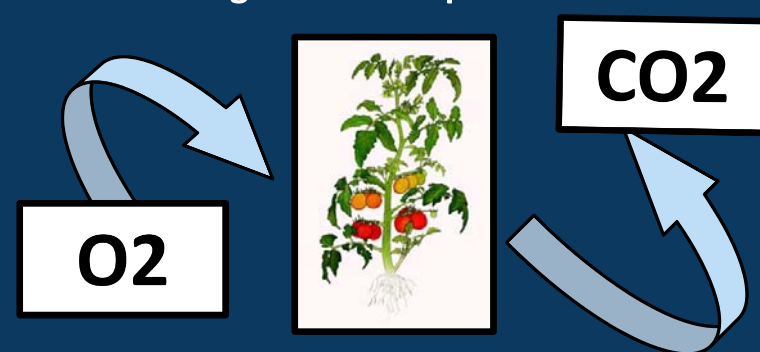
25 cm diameter – fits with 12U standard

Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

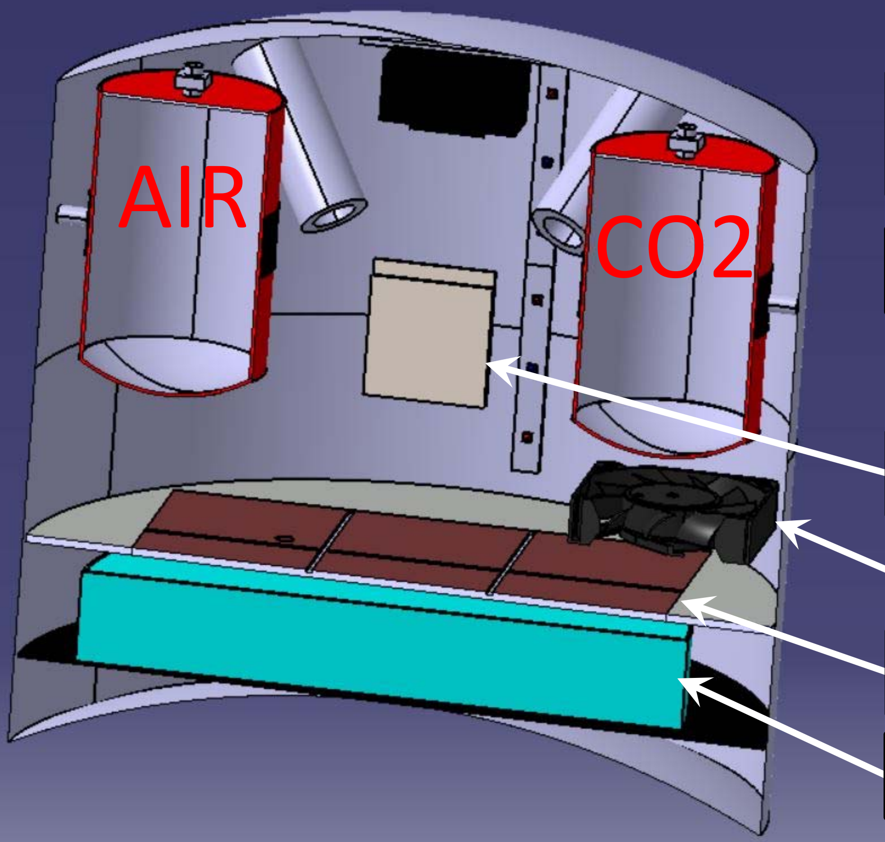
Gas tanks: Air and CO2

LED arrays

Night time: Respiration



PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



25 cm diameter – fits with 12U standard

Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

Gas tanks: Air and CO2

LED arrays

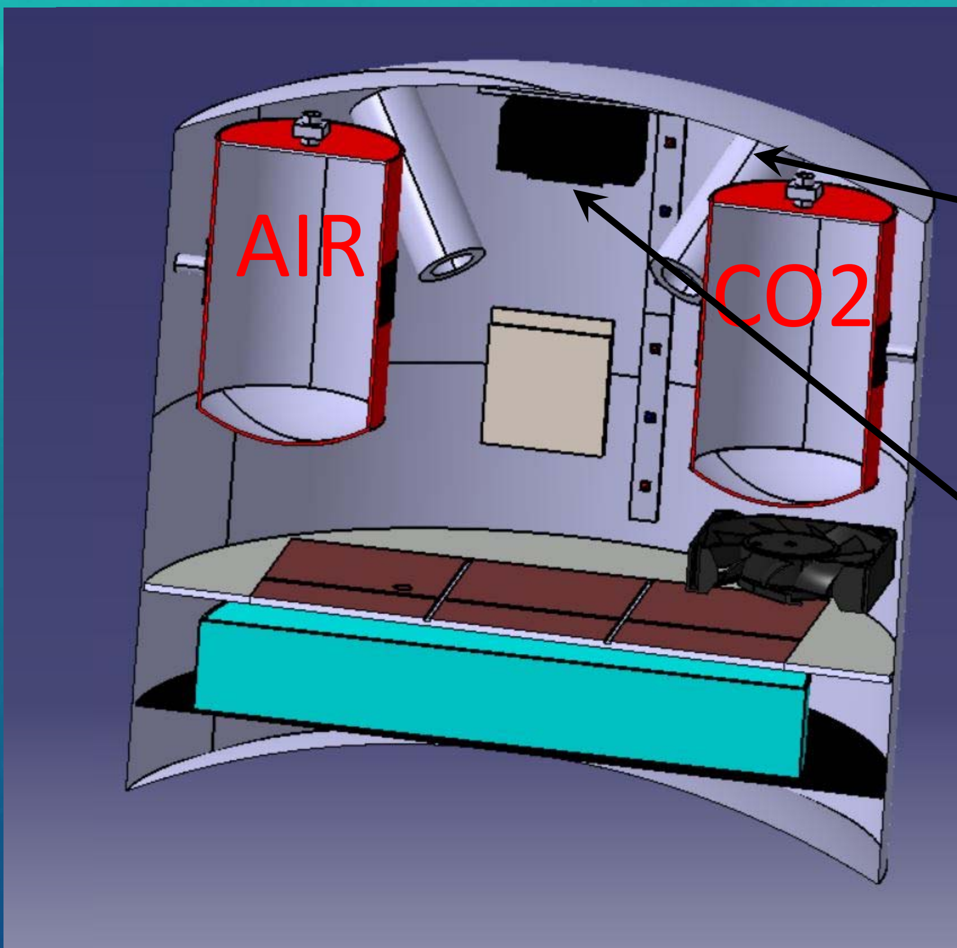
Peltier Cells

Electric fan

Seeds matrix (3x3)

Water bags (with and without solved nutrients)

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



INSTRUMENTATION

HYPERSPECTRAL IMAGING

- **CHLOROPHYLL SENSING**
- **LEAF HEALTH, GROWTH AND WATER STATUS**

CAMERA

AIR COMPOSITION, TEMPERATURE AND PRESSURE MONITORING

POWER BUDGET (PER-DAY, WORST CASE)

Component	Max Power (W)	Duty Cycle (per day)	Average Power (W)
Transceiver – TX chain	2.805	0.014	0.03927
Transceiver – RX chain	0.396	1	0.396
OBDH	0.9	1	0.9
LED matrix	1.8	0.67	1.2
Air pump	0.05	0.5	0.025
Air fan	2.88	0.1	0.288
H2O Electrovalves (x13)	4.55	0.001	0.004
Air Electrovalves(x8)	2.8	0.001	0.003
Peltier Cell	10	0.05	0.5
Infrared Spectrometer	0.9	0.014	0.0126
H2O pump (x2)	0.1	0.0003	0.00003
Power Consumption			-3.37
Generated Power (4 solar cells)	9.08	0.5	+4.54
Total Margin		**+ 1.17 W**	

POWER BUDGET (PER-DAY, WORST CASE)

PER-ORBIT POWER BUDGET (Worst case budget)	
Average Power Consumption	-5.49 W
Generated Power (4 solar panels)	+4.54 W
Margin (4 solar panels)	-0.95 W
Generated Power (6 solar panels)	+ 6.13 W
Margin (6 solar panels)	**+ 0.64 W**

H2O pump (x2)	0.1	0.0003	0.00003
Power Consumption			-3.37

BATTERY PACK SIZING
Two COTS CubeSat Li-Ion cells (19.050 Wh) can support multiple seed-to-seed cycles

Total Margin	+ 1.17

MASS BUDGET

Payload Components	Mass (kg)	Bus Components	Mass (Kg)
Primary Pressurized Tank	3.400	Standard 12U Structure	2.000
H_2O, O_2 and CO_2 Tanks	1.650	Solar panels	1.000
H_2O	1.000	EPS + Battery pack	0.300
CO_2	0.500	Thermal Blankets	0.250
O_2	0.500	Harness	0.200
Seed Matrix	0.200	Antenna system	0.050
Air Fan	0.145	Motherboard	0.050
Peltier Cells and heaters	0.250	On-Board Computer	0.025
Electrovalves and pumps	0.400	Transceiver	0.025
LEDs and related boards	0.080		
Infrared Spectrometers	0.230		
Payload components mass	8.355	Bus components mass	3.900
Total Mass		**12.255 Kg**	

PRELIMINARY RISK ANALYSIS

ID	Risk and consequence	P	S	P x S	Action
MS01	A **launch delay** implies that **seeds start growing before** the **satellite launch** and deployment, with the consequent failure of the mission	A	4	Very Low	**The seeds do not start growing if not watered.**
TC01	The **pressure vessels fail** to **obtain qualification** for space flight	B	4	Low	All the pressure vessels will consider **high safety margins** (**at least 20**). The **air tanks** (storing gases at higher pressure) will be accommodated **inside the main pressure vessel**, in order to provide the system with **double redundancy**.
TC02	The **external tank explodes** as result of an overpressure	A	5	Low	The main pressure vessel **nominal pressure is low** (**0.25 atm**). Multiple mechanical **over-pressure valves** will be implemented in order to avoid possible explosions
TC03	A single failure on an ECLSS component causes the **micro-tomato plant death**	B	4	Low	All the **critical ECLSS** components (Peltier Cells, LEDs, fan) will be **redundant**.

PROJECT STATUS

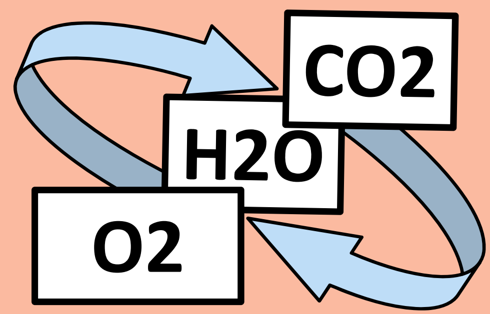
THE MICRO-TOMATO SPECIES HAS BEEN DESIGNED FOR SPACE APPLICATIONS

THE TEAM HAS STARTED A TESTING CAMPAIGN AIMED AT ASSESSING ITS VITAL PARAMETERS IN SPACE

HYPOBARIC PLANT GROWTH AT 0.25 atm

WILD-TYPE COMPARISON TEST

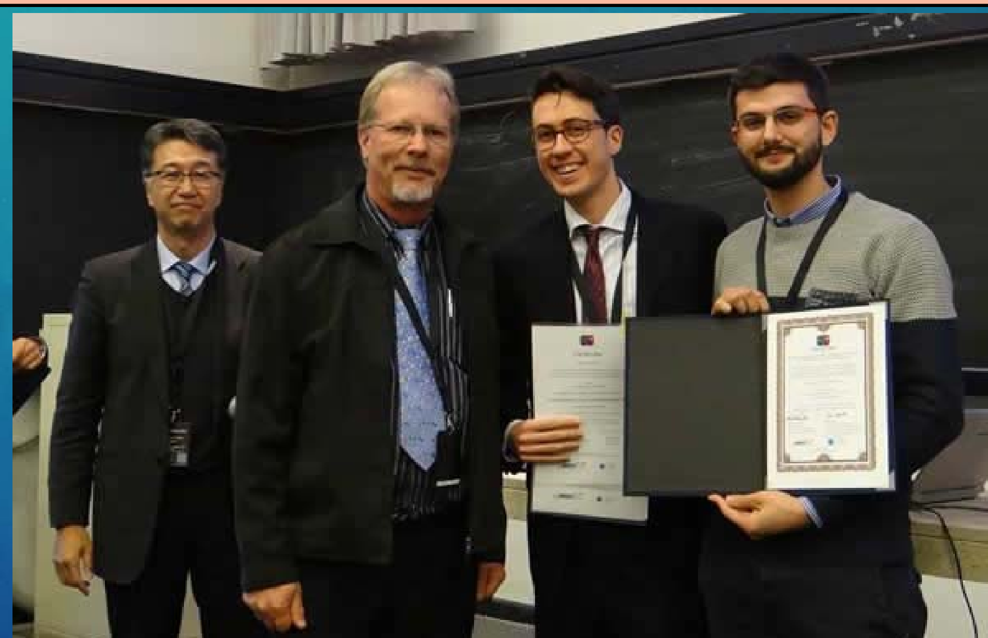
AUTO-FEEDING CONDITIONS TESTS



PROJECT STATUS

THE CUBESAT PRELIMINARY DESIGN HAS BEEN PRESENTED AT THE 5th PRE-MISSION IDEA CONTEST IN DECEMBER 2017

UNISEC GLOBAL
University Space Engineering Consortium



THE PROJECT WAS AWARDED WITH THE 2nd PLACE AT THIS INTERNATIONAL CONTEST