THE GROWTH OF TOMATO PLANTS MICRO-TOM IN SPACE ENVIROMENT

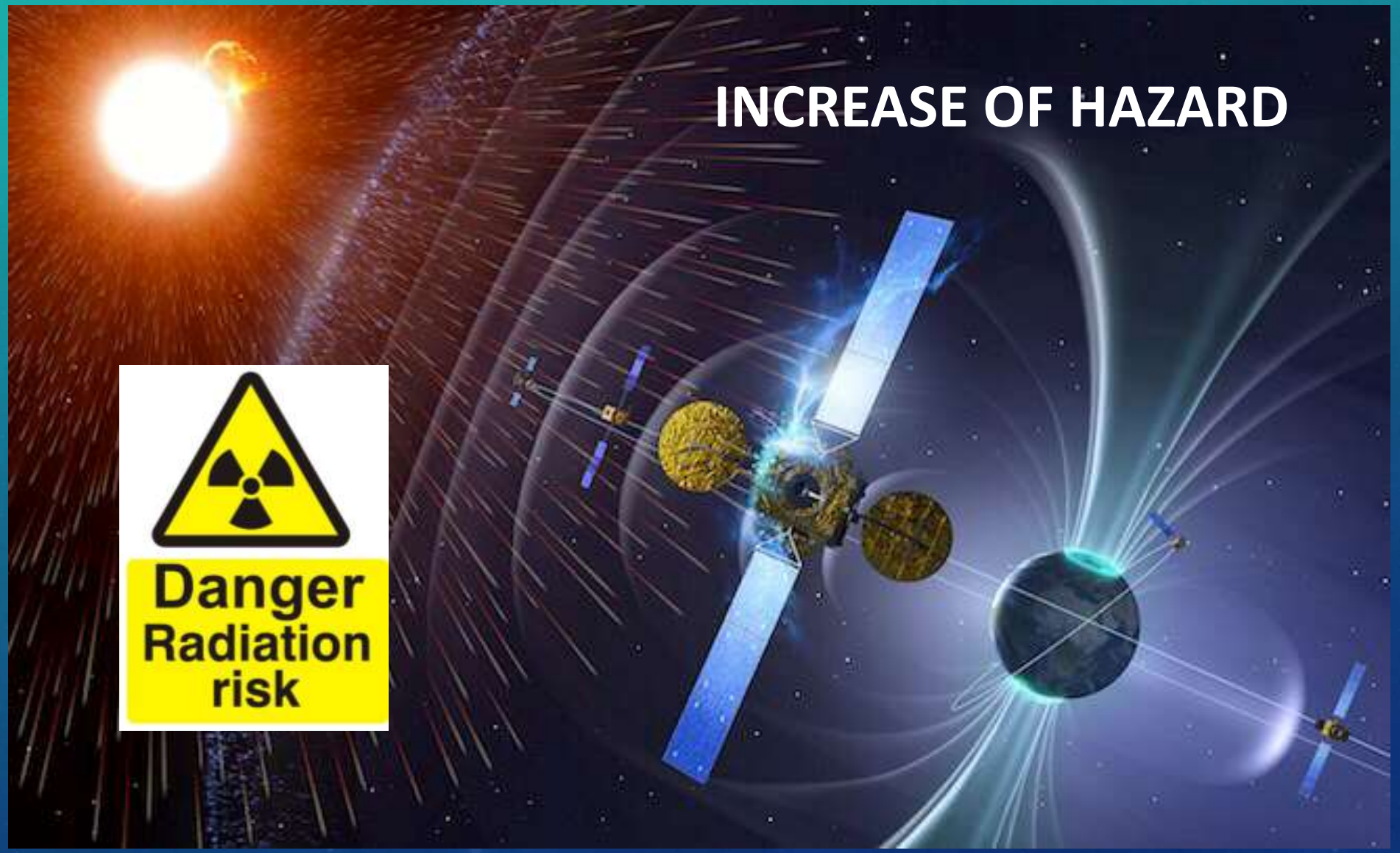
TEAM MICRO-TOM

Pre-Mission Idea Contest (PreMIC) - The Fifth UNISEC Global Meeting
University of Rome "La Sapienza", Rome – Italy, 2 December 2017
Presenters: Giulio Metelli and Paolo Marzioli

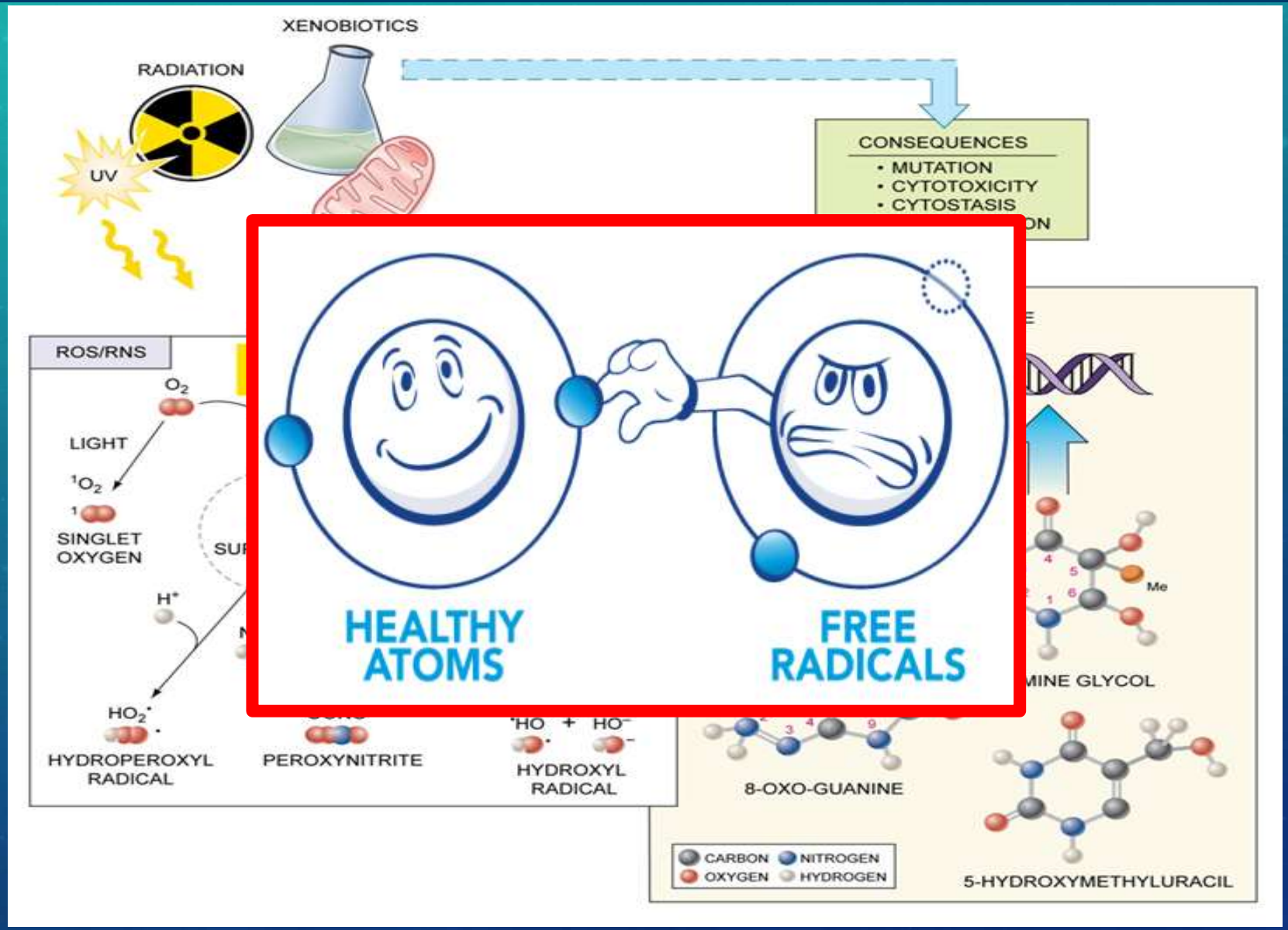


SAPIENZA
UNIVERSITÀ DI ROMA
UNISEC GLOBAL
University Space Engineering Consortium

MICROGRAVITY AND RADIATIONS IN SPACE



ROS AND DNA DAMAGE



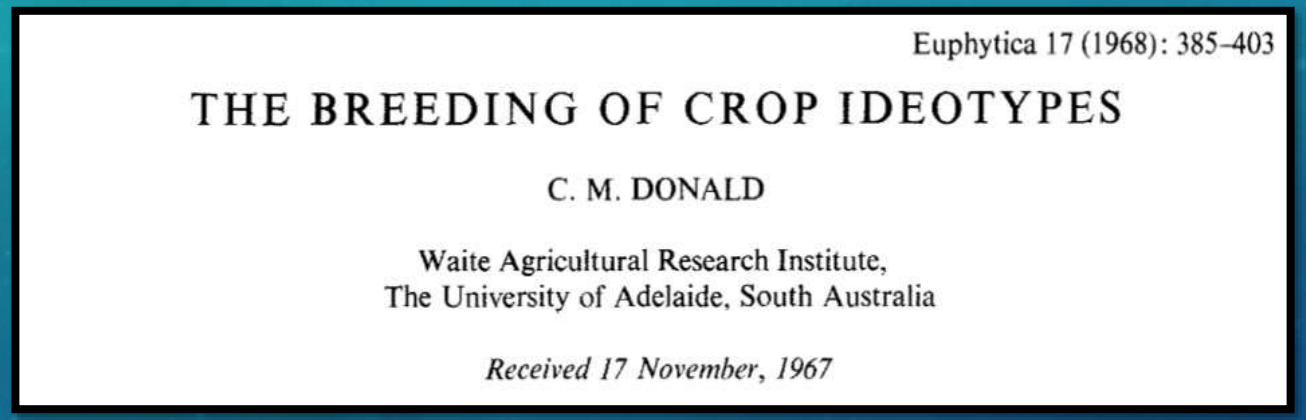
BIOXTREME PROJECT

agenzia spaziale italiana

BIOXTREME

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

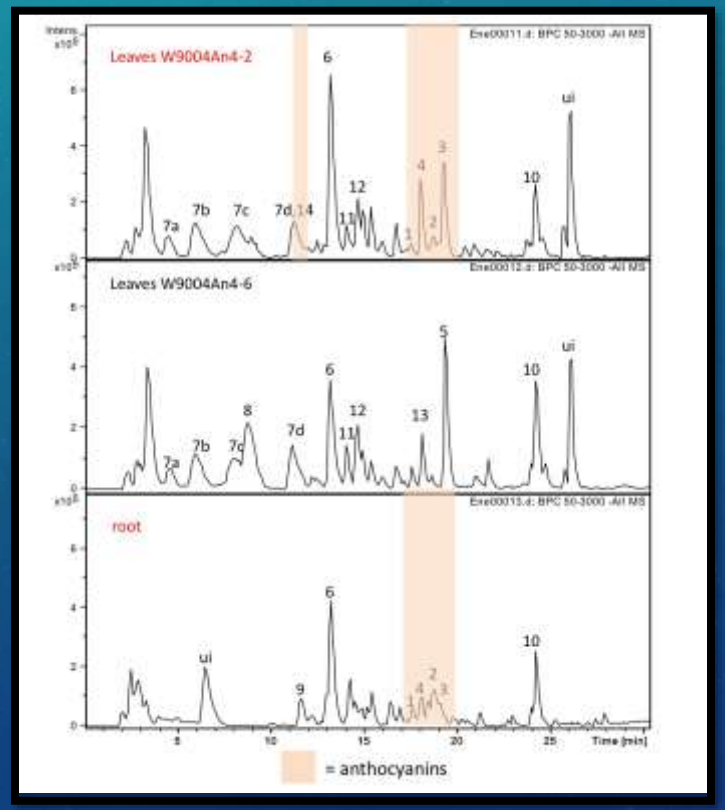
- Development of conceptual theoretical model
- Selection of base material
- Incorporation of desirable characters into single genotype
- Selection of ideal or model plant type

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

MICRO-TOM TAILORED FOR SPACE



1 delphinidin

2-4 petunidin

PLANTS IN SPACE A KEY FACTOR IN BIOREGENERATIVE SYSTEM

Light

O_2

H_2O

Food

CO_2

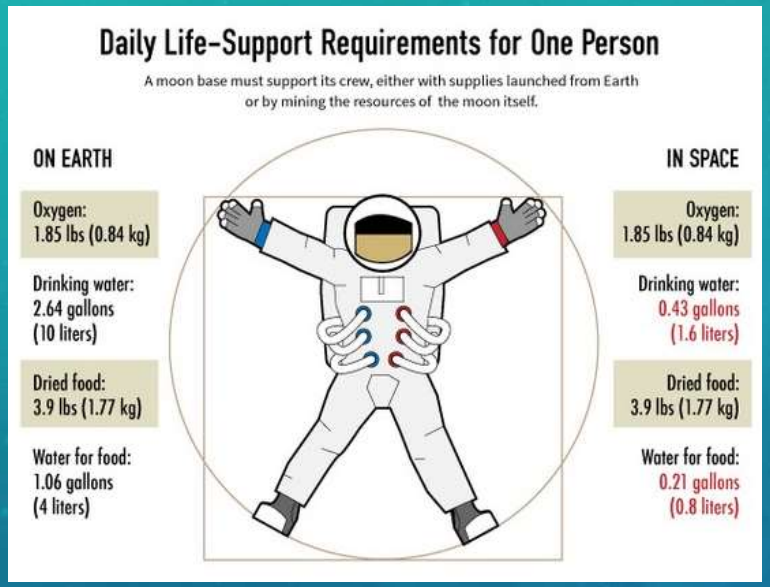
CO_2

H_2O Nutrients

Waste Processor (Microbial Bioreactor)

Waste H_2O & Solid Waste

FOOD IN SPACE



Astronaut daily meal

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

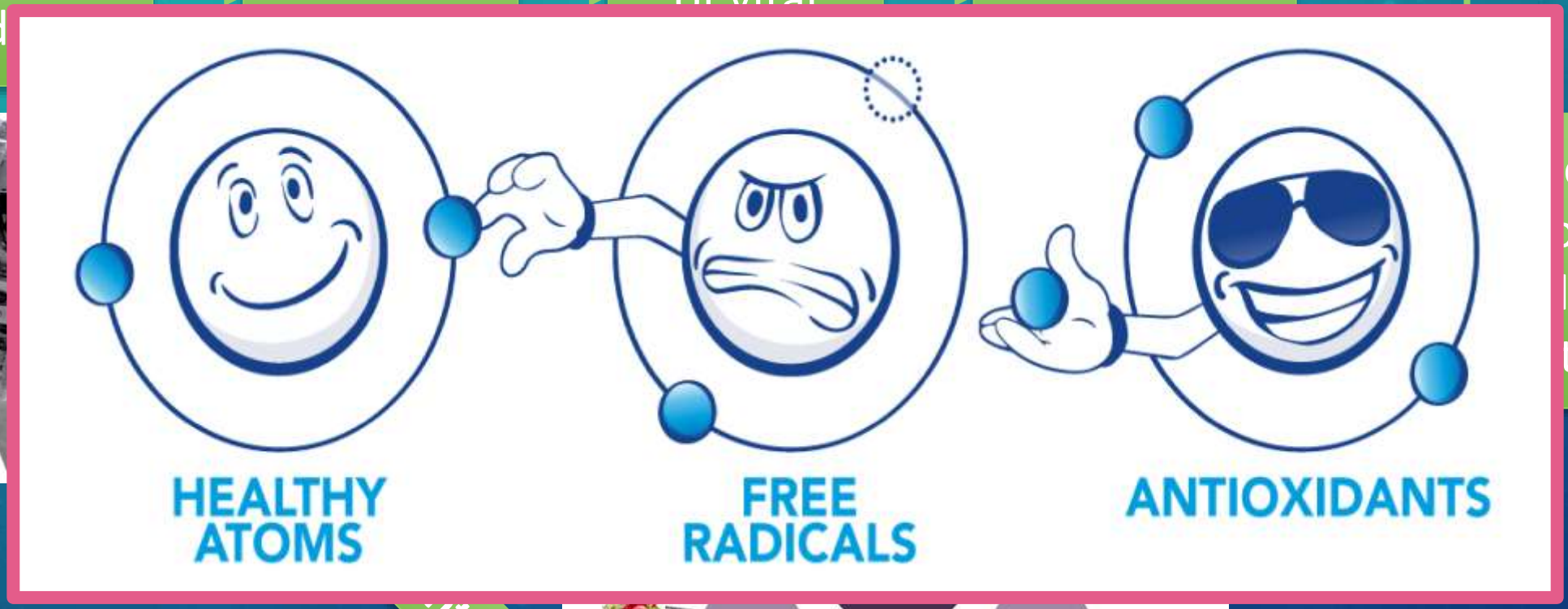
Lyophilized

vs

Fresh

BENEFICIAL EFFECTS OF ANTHOCYANINS THERAPY ON HUMAN HEALTH

Adverse cond → Oxidative → Oxidation of vital → Development



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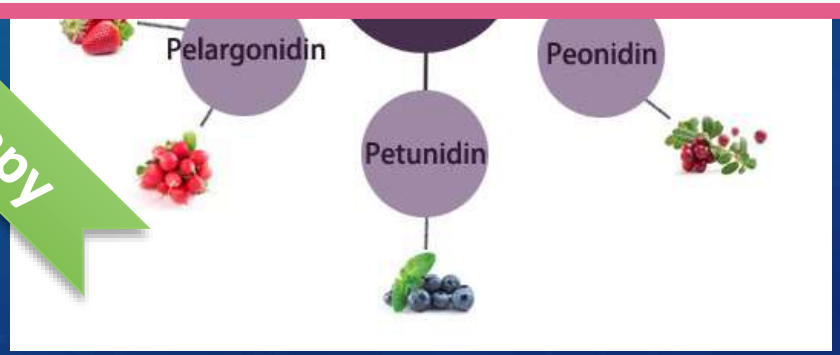


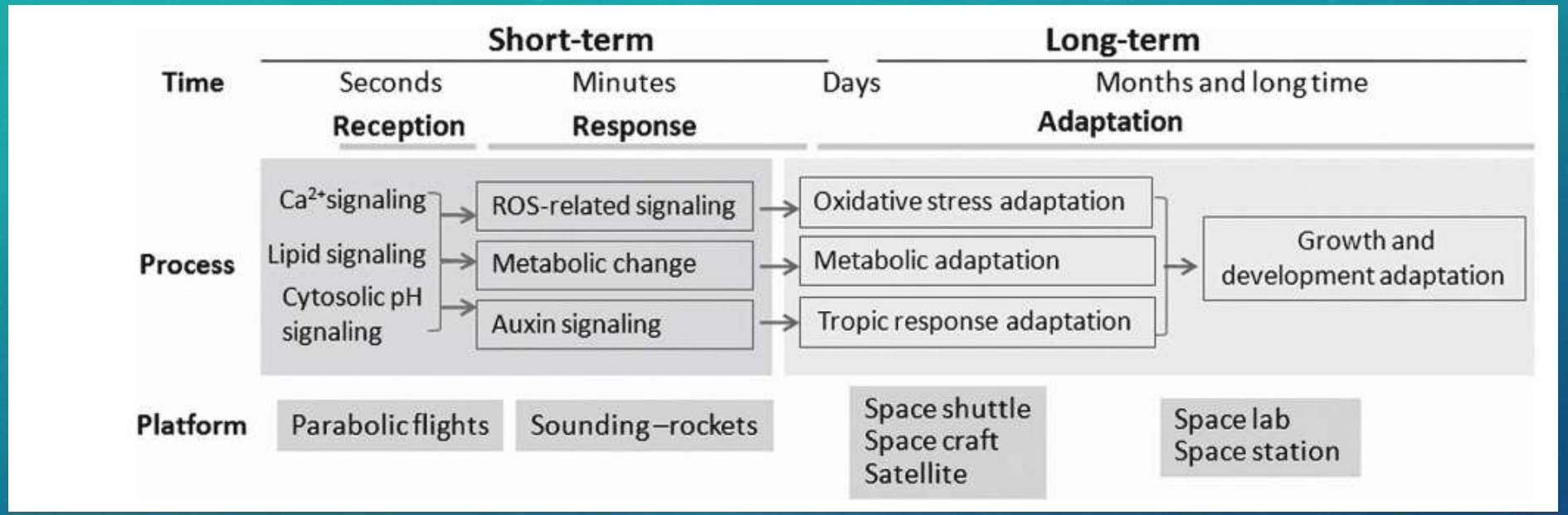
SIMULATED MICROGRAVITY 1*10^{-5} G

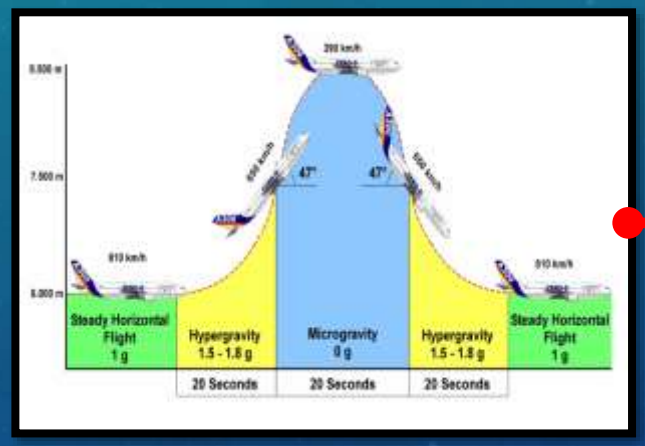
LED LIGHT

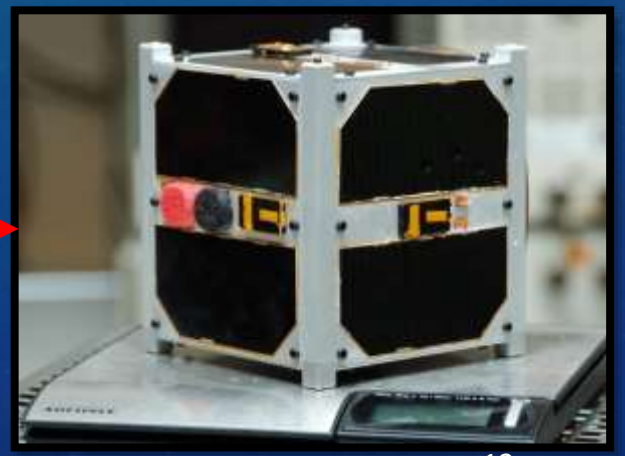
CLINOSTAT

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

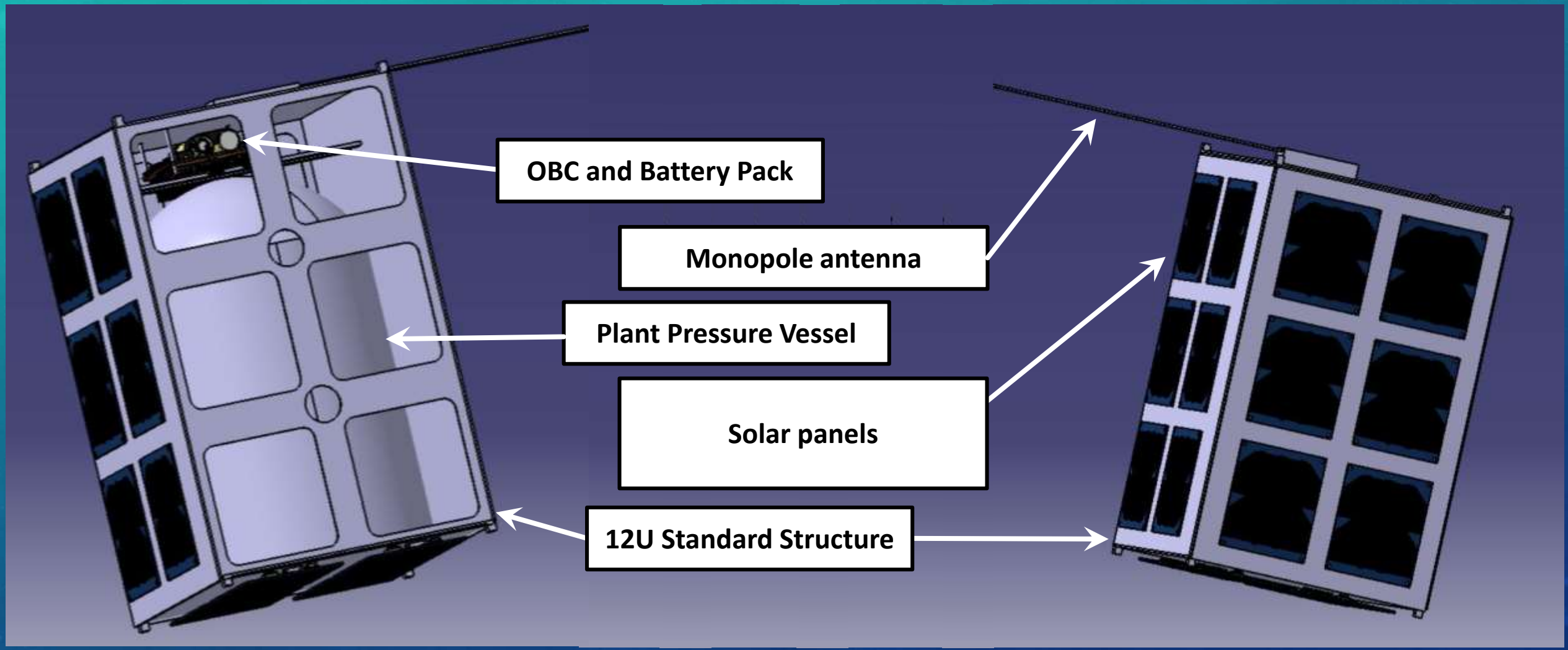
DAY/NIGHT CYCLES CONTROL

TEMPERATURE CONTROL

PLANT VITAL PARAMETERS MONITORING

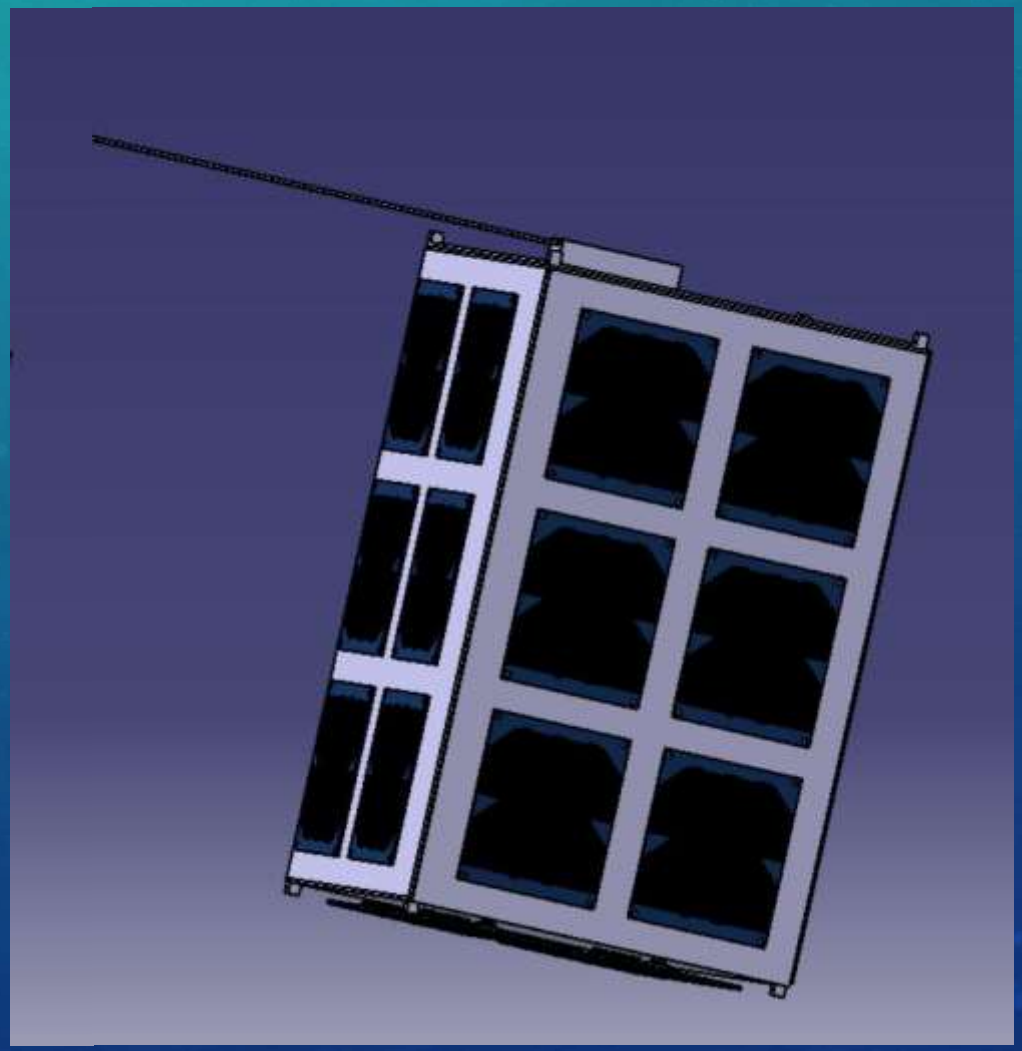
The described functions are compatible with the Micro-Tomato plants on a 12U Cubesat

12U CUBESAT OUTLINE

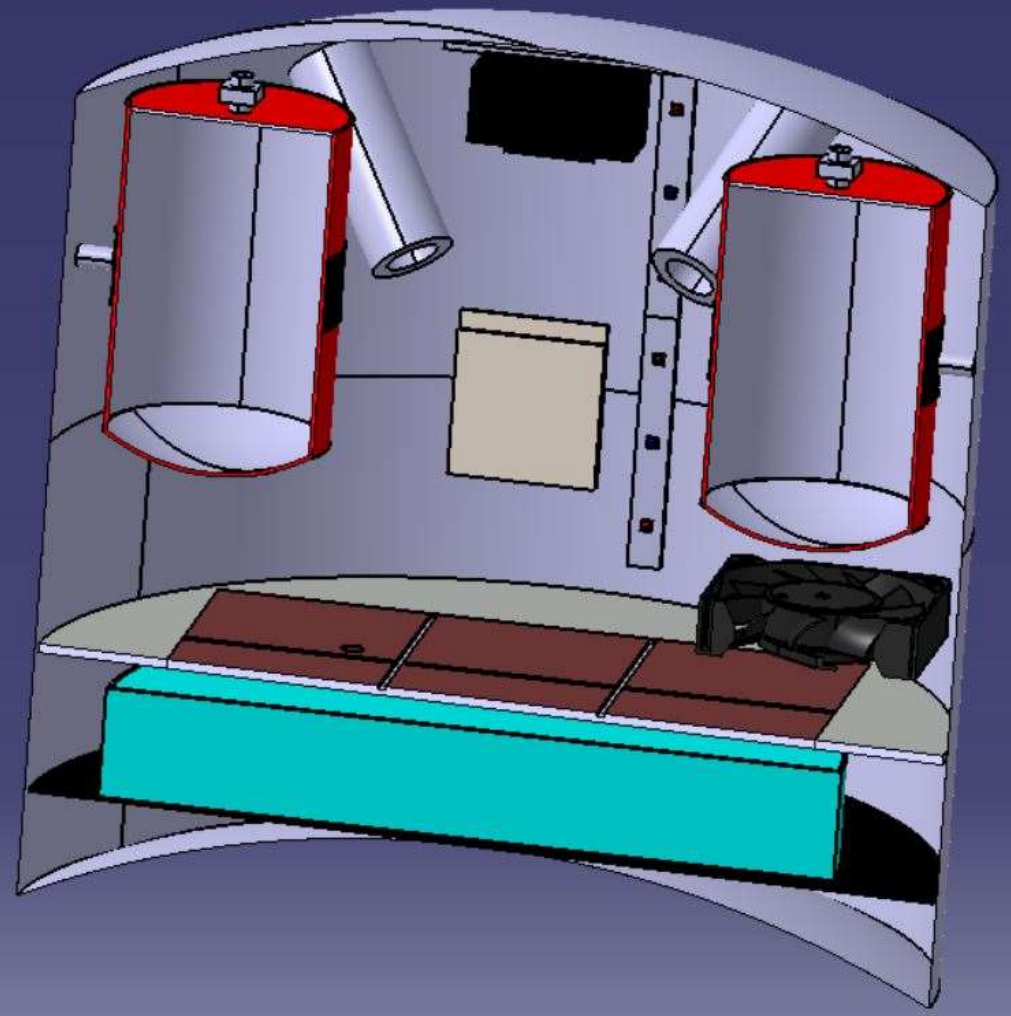


SATELLITE DESIGN

- 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



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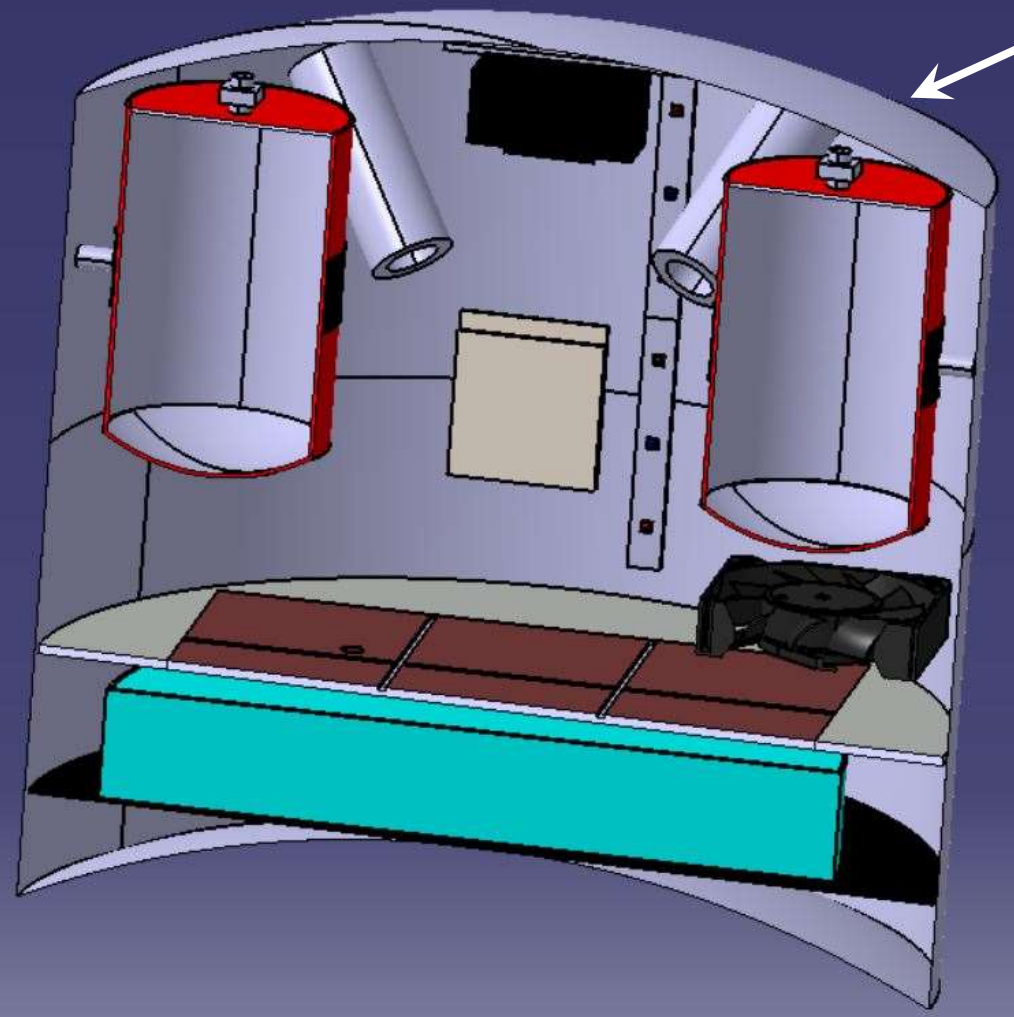
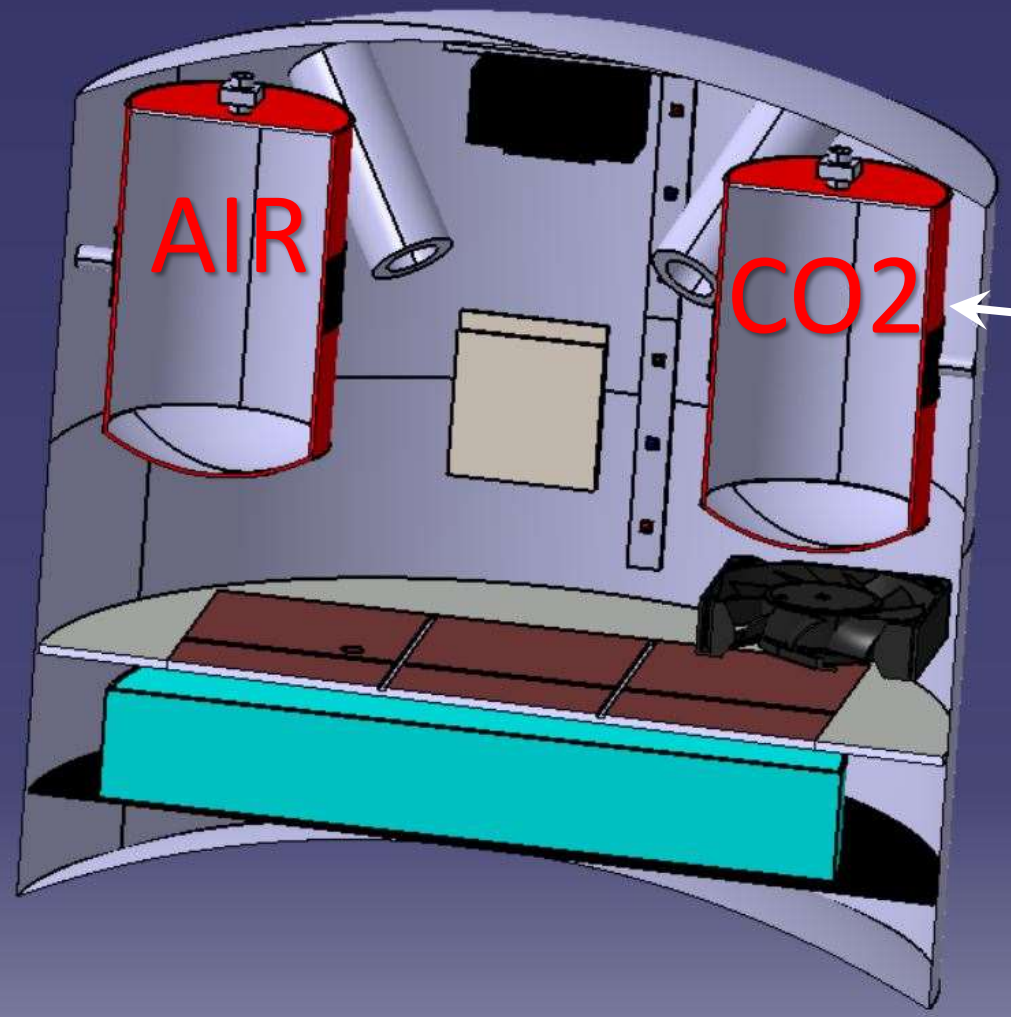


25 cm diameter – fits with 12U standard

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

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



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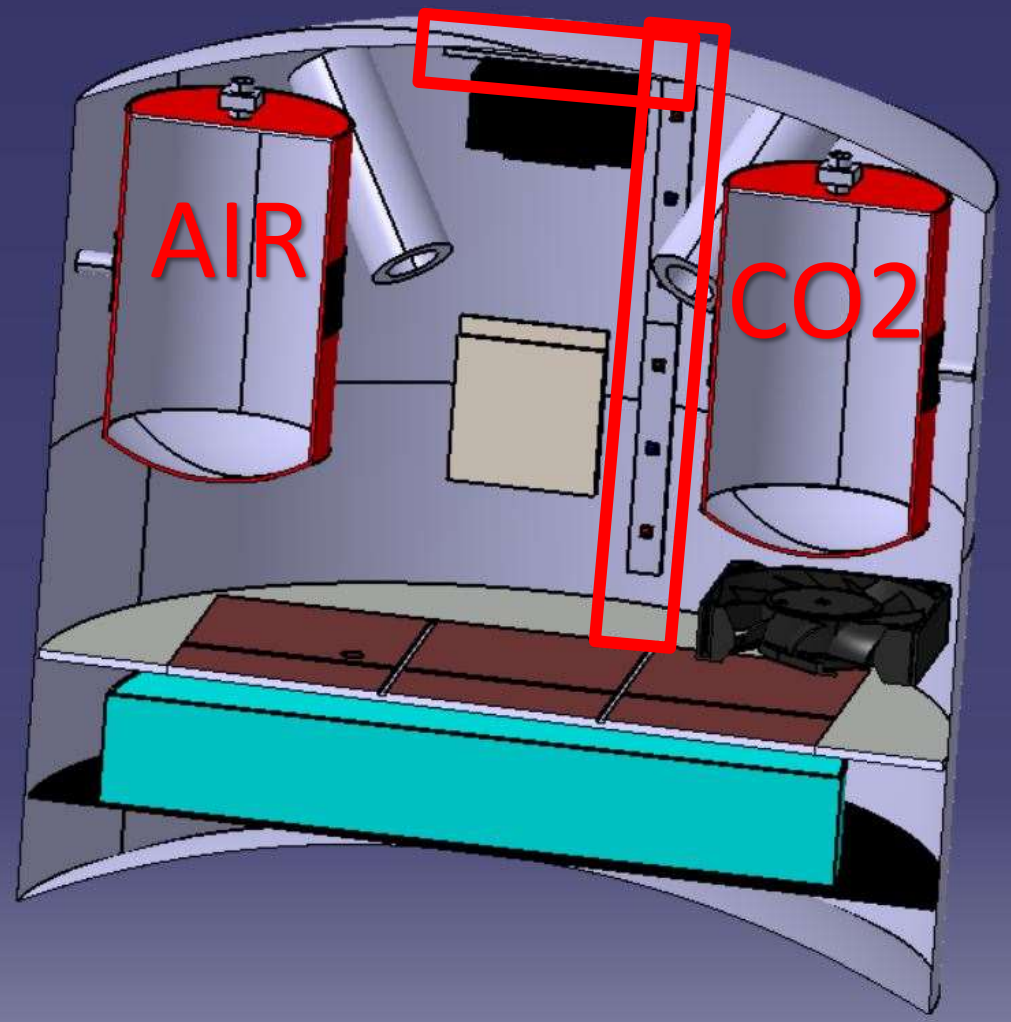
Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

Gas tanks: Air and CO2

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



25 cm diameter – fits with 12U standard

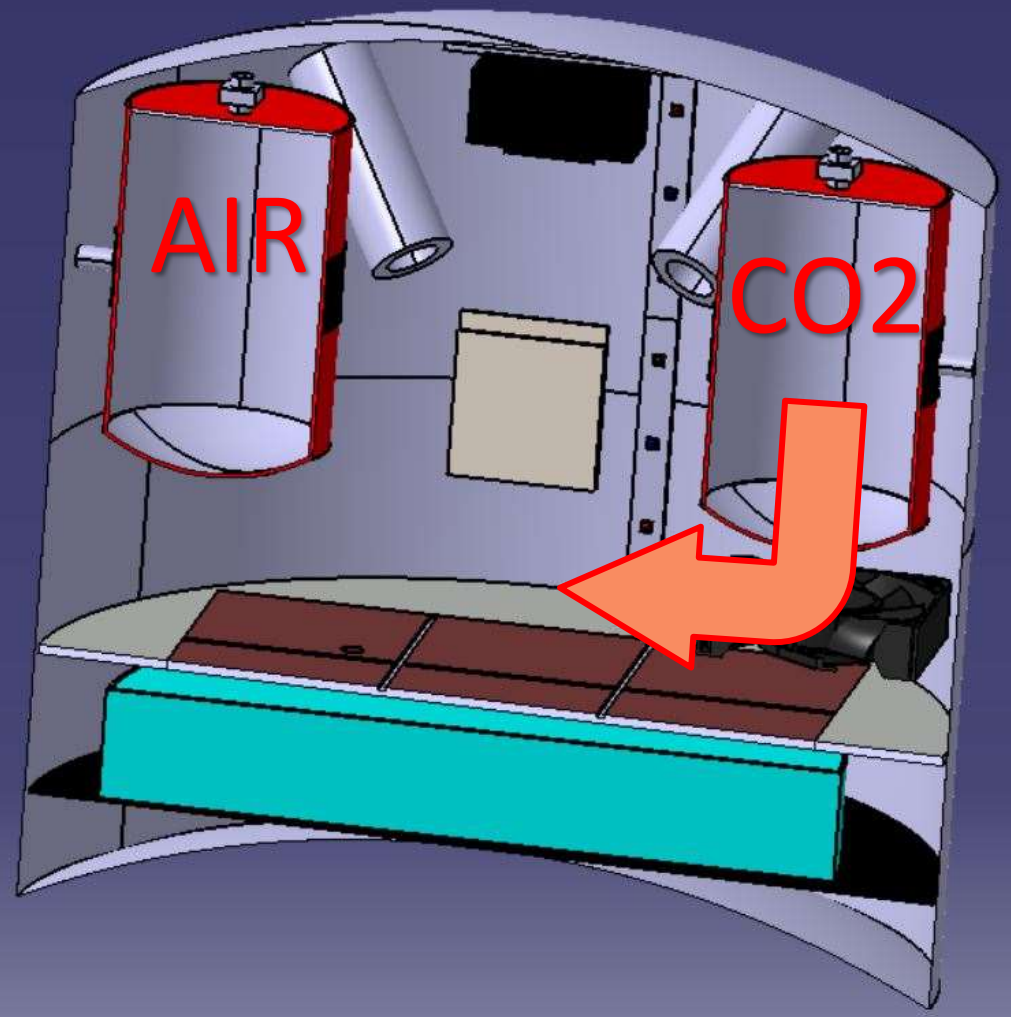
Pressurized at 25 kPa (0.25 atm) –
Structures safety factor > 20

Gas tanks: Air and CO2

LED arrays

- Top
- Vertical Bars

PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



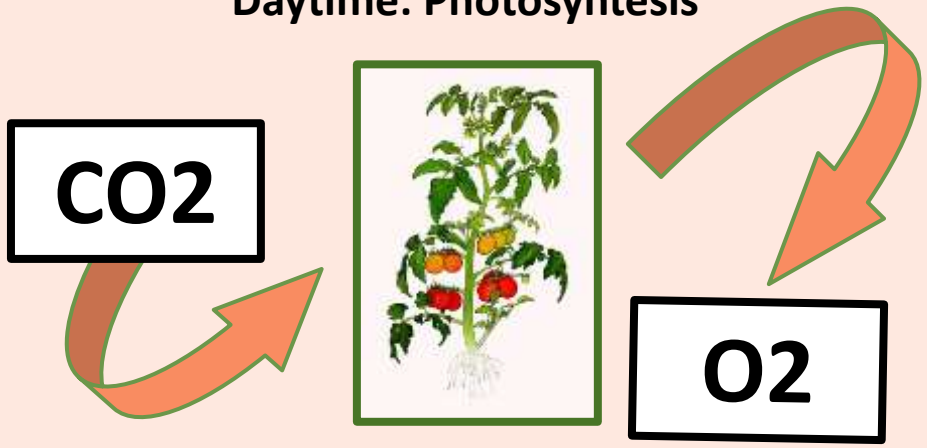
25 cm diameter – fits with 12U standard

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

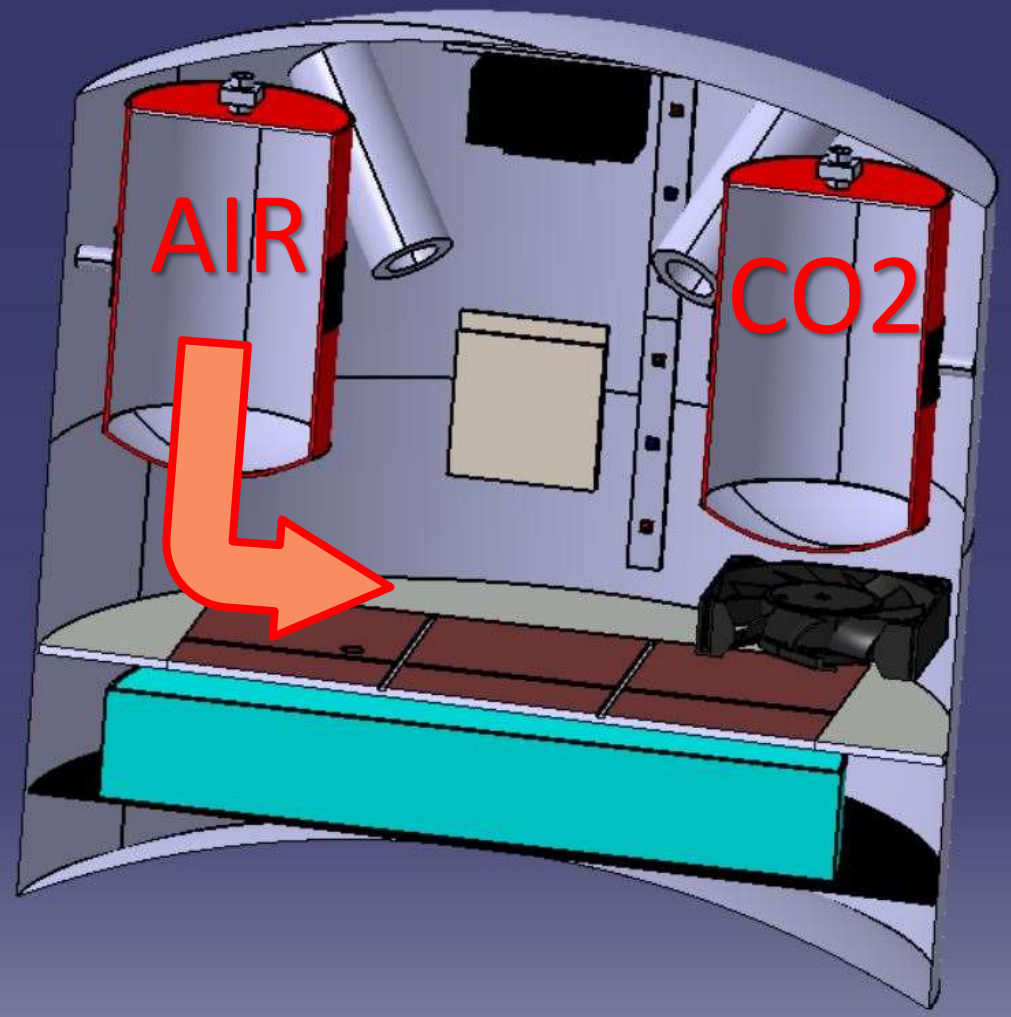
Gas tanks: Air and CO2

LED arrays

Daytime: Photosyntesis



PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



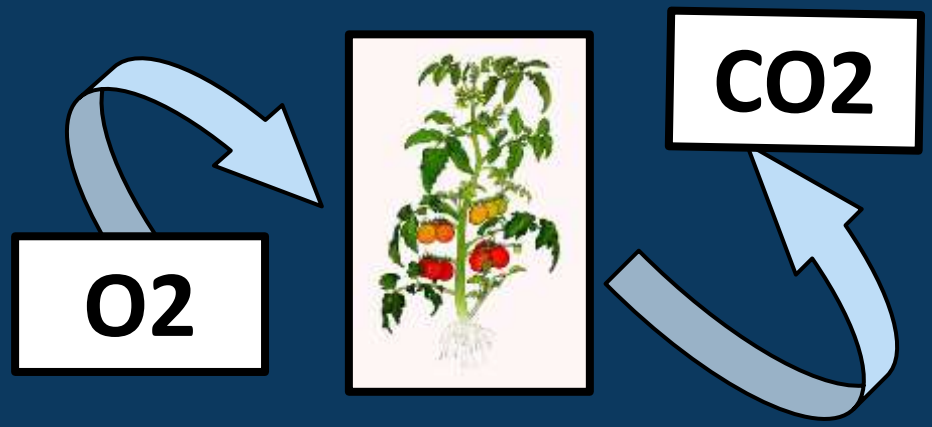
25 cm diameter – fits with 12U standard

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

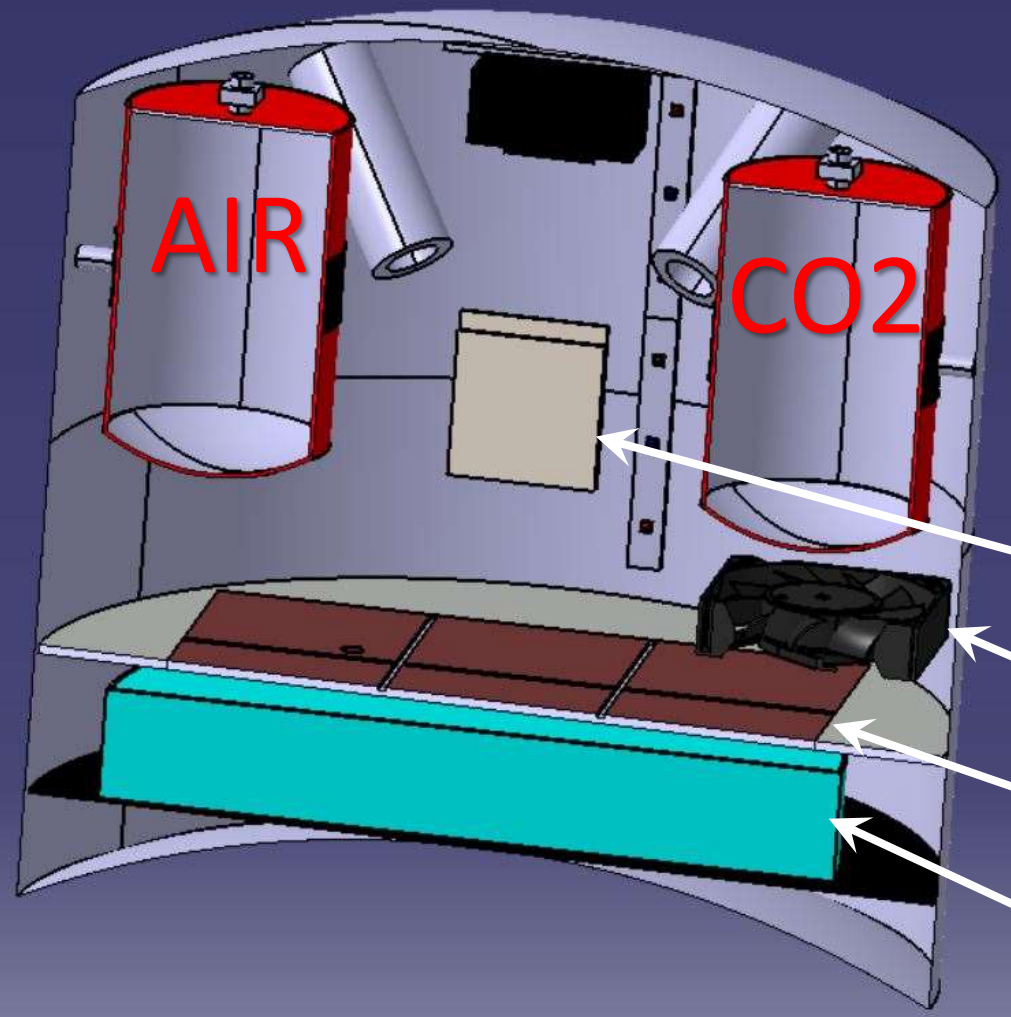
Gas tanks: Air and CO2

LED arrays

Night time: Breathing

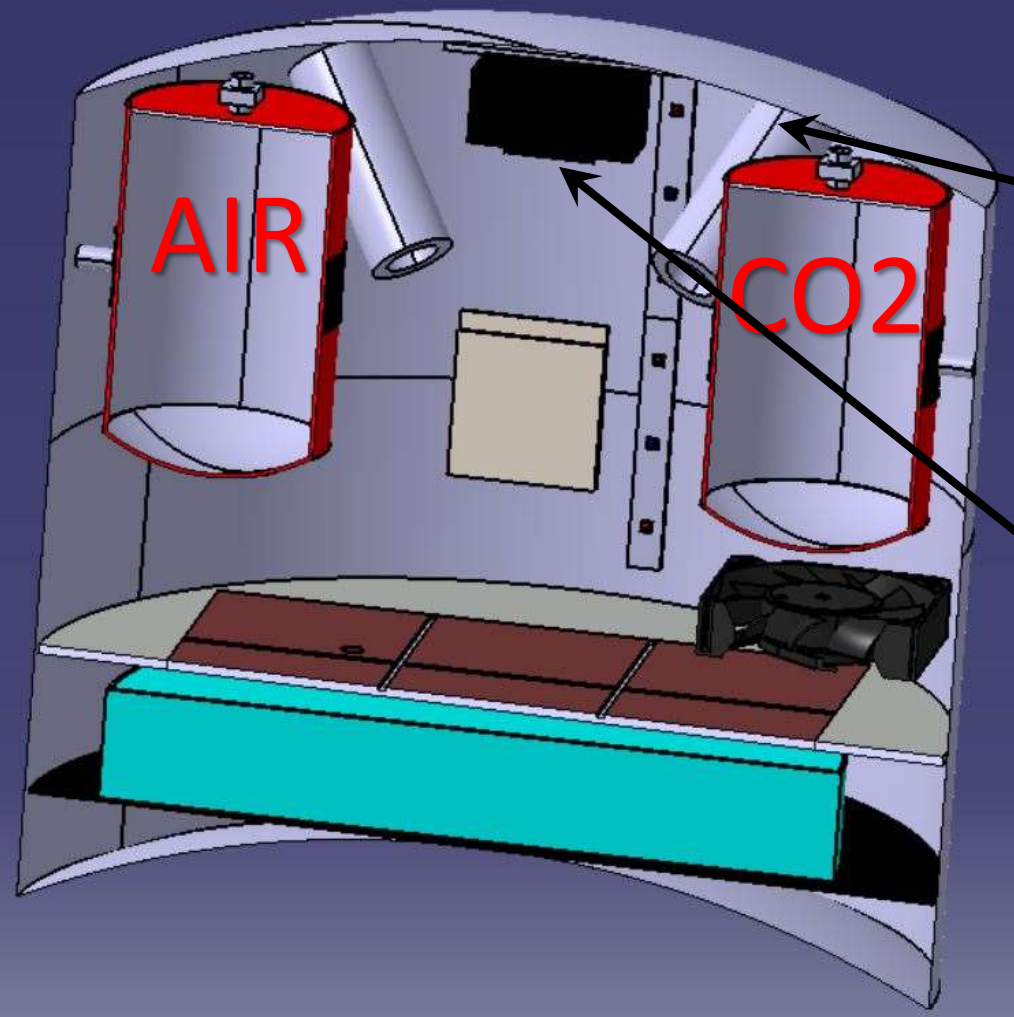


PRESSURE VESSEL OUTLINE – ENVIRONMENTAL CONTROL SYSTEM



- 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

Pressurized at 25 kPa (0.25 atm) –

INFRARED SPECTROMETERS

Gas tanks: Air and CO2

CHLOROPHYLL SENSING

array

LIFE PARAMETERS MONITORING

Peltier Cells

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
H2O, O2 and CO2 Tanks	1.650	Solar panels	1.000
H2O	1.000	EPS + Battery pack	0.300
CO2	0.500	Thermal Blankets	0.250
O2	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**.

CONCLUSIONS

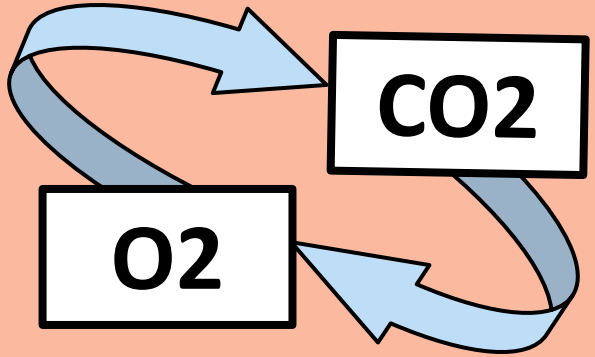
THE MICRO-TOMATO SPECIES HAS BEEN DESIGNED FOR SPACE APPLICATIONS

THE TEAM IS READY FOR A TESTING CAMPAIGN AIMED AT ASSESSING ITS VITAL PARAMETERS IN SPACE

HYPOBARIC PLANT GROWTH AT 0.25 atm

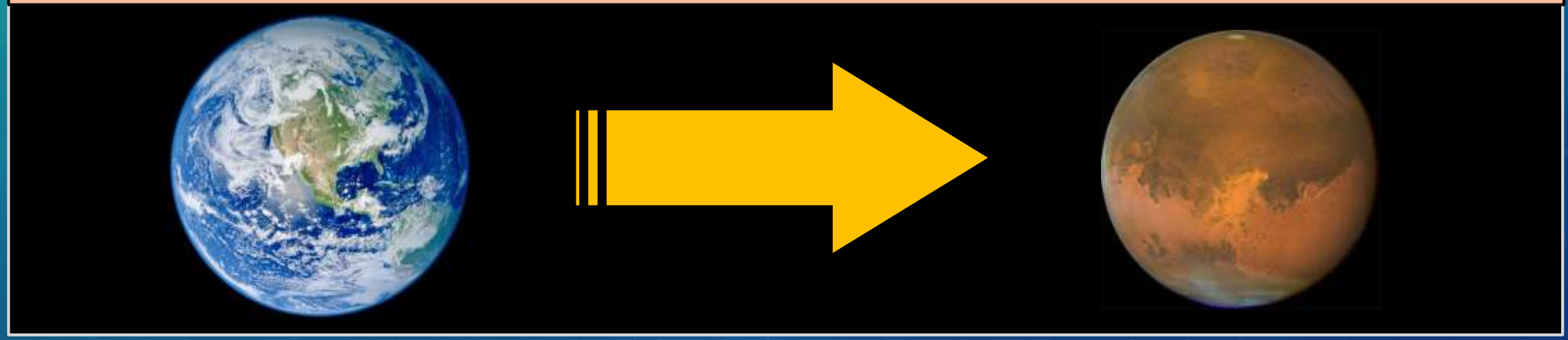
WILD-TYPE COMPARISON TEST

AUTO-FEEDING CONDITIONS TESTS



CONCLUSIONS

THE IN-ORBIT TESTING OF THE MICRO-TOMATO PLANTS GROWTH IS AIMED AT SUPPORTING HUMAN NUTRITION DURING INTERPLANETARY TRAVELS



THANKS FOR YOUR ATTENTION

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ADDITIONAL SLIDES

THERMAL ANALYSIS – AIR TEMPERATURE OF PRESSURE VESSEL