AGROTES DE L'ESPACE

Biotic Inter-Operable Plant System

PROJECT REPORT

THE BIOTIC INTER-OPERABLE PLANT SYSTEM

The BIOS - 1 is an advanced, scalable, fully autonomous, and self-sustaining space plantation pod system. Built for a team of six astronauts, BIOS - 1 can run on both, spacecrafts, and terrain. Our project aims to provide the Astronauts with nutrients in a long-lasting, easily absorbed form—freshly grown fresh fruits and vegetables while adding fresh food to the astronauts' diet and enhancing happiness and well-being on the space station. In the absence of gravity, plants use other environmental factors, such as light, to orient and guide growth.

When crews venture further into space, traveling for months or years without resupply shipments, the vitamins in pre-packaged form break down over time, which presents a problem for astronaut health. Hence, we plan on growing a variety of plants, including three types of lettuce, Chinese cabbage, mizuna mustard and red Russian kale. We also have peppers, cherry tomatoes as well as a few different types of berries included in our project. All the cultivation will take place hydroponically in an enclosed and regulated environment. Not only are these foods nutrient-dense and provide a tremendous number of benefits to the astronauts but can also be added to a variety of cuisines.

These foods provide a variety of vitamins, minerals and fibre required for sustaining astronaut health. They also provide antioxidants which will protect cells from damage from unstable molecules called free radicals. We also plan on planting blueberries, cranberries and strawberries which will help reduce damage to the astronauts' brain due to cosmic radiation. Lycopene in cherry tomatoes may support bone health. A study found that women who consumed tomato products saw lower rates of bone density loss compared to those who consumed less lycopene. This can pose to be an added advantage for astronauts since the lack of gravity on the station and approximately 1/3rd gravity on mars can affect bone density of astronauts.

Our project is built to meet new missions and operational and environmental constraints. The whole crop production system can cultivate the required amount of food while in transit to the Martian or the lunar surface and will still function when its touched down. To tackle the lack of gravity while in transit to the destination, we adapted pseudo gravity technique via rotation which creates centrifugal force but only limited to the system and not to the station. To maintain crops growth in terms of data the sensors will come into play, those sensors will share the data to the life support system which will take necessary actions which will boost up the growth of an individual crop.

The life support of the crop production system is designed in such a way that it monitors each seedling's growth. It analyses the data received from the CAPS and directs just the nutrient amount required for the crop, coordinating with the nutrient delivery network.

The CAPS is the central "managing authority," the operation code of the BIOS - 1 which manages all inputs, analyses them, and accordingly acts. CAPS takes data from multiple PH, temperature, light sensitivity, water level, water constituent, electrical conductivity and IR imaging sensors and matches the same with the CAPS PLANT RESEARCH DATABASE. This database is a collection of records with details on the nutrient, light, water, and other requirements for each plant. When planting, the astronaut registers in CAPS the plant planted in a particular pod which CAPS uses to do this. CAPS uses specialized sensors made to operate in the BIOS - 1's-controlled environment.

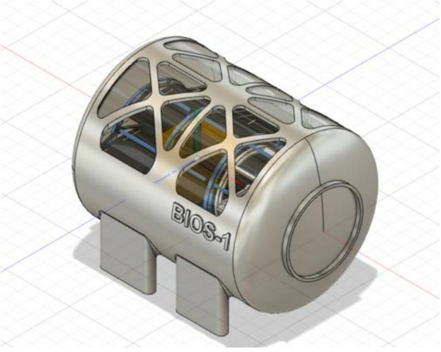
The water system which is responsible for accepting polled sensor data and accordingly deliver the required water for each plant as per instructions from the operating code and is internally connected to the wireframe of the design further assist the ECC in nutrient delivery by employing its existing infrastructure to dual uses. The water also features individual per-pod electronic check valves to ensure each plant gets just the amount of water it needs.

For growing plants on the BIOS -1, an efficient lighting system is required for the proper functioning of the system. Adjustable spectrum COB (chip on board) LED grow lights that emit light with wavelengths between 280nm and 800nm are used to maximize the efficiency of plant growth and energy usage on the BIOS - 1. The entire light system is controlled by a centralized automated computer software that controls the quality, quantity and duration of light received by each plant. To do this it uses available plant growth data and keeps updating this database as it gains experience.

STRUCTURE AND MECHANICS

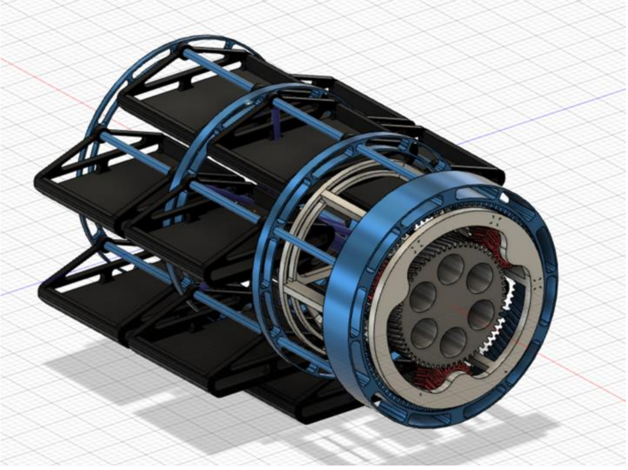
PRESSURE VESSEL

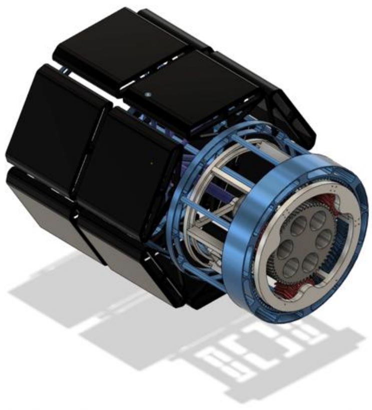
The main pressure vessel of the BIOS module is a cylinder of 5.6 m in diameter and 7.8 meter in length. It' s made up of double layered 7000 series aluminum with Kevlar padding in between. This is done to protect module from deep space micrometeorites. The pressure vessel has an Isogrid embossed on to them. This is done to increase the modules structural integrity. A total of 18 Double layered glass windows with a Polycarbonate layer is present on the top side for natural sunlight to enter the module.



CORE

The core module / Spinning element inside the pressure vessel is designed, keeping in mind about the feasibility of the parts to be manufactured while reducing weight. The core module will have 12 Pods with a total farmable are of 28.8 m^2. They will be pivoted on a central supporting structure. In this way they are able face radially inward during the orbital state and be able to suspend downwards when deployed on the Martian/ lunar surface.



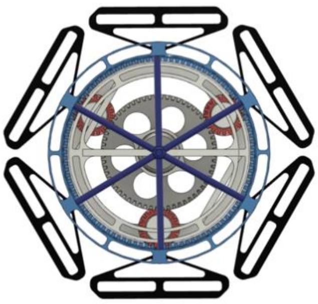


WEIGHT REDUTION

The main challenge for us in this project was the power consumption of the motor to spin. Our initial design parameters demanded a power output of almost 600KW. By reducing the weight, the torque required by the motor to spin will brought down ultimately bringing down the demand for power. After looking at different materials for the fabrication of the spinning element we finally found the aerospace grade T-800 carbon composite is the best choice due to it high tensile strength and low weight. with a density of just 1.8g/cm^3 and with an infill of 30% we were able bring down the weight from around 25 tons to just 2.8 tons. Moreover, weight reduction has been done on the gear drive to further reduce mass. These improvements ultimately brought down the power consumption to 45KW

GEAR DRIVE

The gear drive is designed to give the most efficiency. Our initial idea was to use a helical system to spin the core. Soon we realized that by having a planetary gear system it much more efficient in transmitting power and provided higher stability and durability. Our planetary gear system has a mechanical advantage of 1.67. These are some design parameters of the gears.



SUN GEAR: 60 TEETH
PLANETARY GEARS: 20 TEETH
ANNULAR GEAR: 100 TEETH
INPUT RPM: 11.667RPM
OUTPUT RPM: 6.6RPM
INPUT TORQUE: 36457.7 N-M
OUTPUT TORQUE: 64464 N-M

MOTOR

High torque low rpm Maglev Motor is used to rotate the inner module. This is done to simulate artificial gravity through centrifugal force. This gives a natural medium for the plants to grow. An output rpm of 6.6 would be required to simulate an artificial gravity of 0.1G. Therefore, the motor will be of 60 HP with the rotation of 11.667 rpm. The motor will be running on the high voltage Bus of the station. To give a comparable estimate the motor on the Tesla Model S Plaid is of 1020HP. So, we genuinely think the power requirements for the motor are not that high.

LIGHTING SYSTEM AND PLANT DATA

For growing plants on the BIOS-1, an efficient lighting system is required for the proper growth of plants and the functioning of the module.

Apart from light being used as a source of energy for photosynthesis. Light can also be used for a process occurring in plants called photomorphogenesis. Photomorphogenesis is the growth and development of plants in response to certain wavelengths of light. Light exposure triggers several major developmental and physiological events, these include growth and differentiation of the embryonic stem (hypocotyl); maturation of the embryonic leaves (cotyledons); and establishment and activation of the stem cell population in the shoot and root apical meristems.

Phytochromes, cryptochromes, and **phytotropins** are photochromic sensory receptors that restrict the photomorphogenic effect of light to the UV-A, UV-B, blue, and red portions of the electromagnetic spectrum. Chlorophyll, the most abundant plant pigment, is most efficient in capturing red and blue light. Accessory pigments such as carotenes and xanthophylls harvest some green light and pass it on to the photosynthetic process, but enough of the green wavelengths are reflected to give leaves their characteristic colour. Plants use phytochrome to detect and respond to red and far-red wavelengths, cryptochromes for blue light (control stem elongation, leaf expansion, circadian rhythms, and flowering time). and UVR8 for response to UV radiation (protection from UV damage, oxidative stress, and photo repair of DNA damage).

There are at least three stages of plant development where photomorphogenesis occurs:

SEED GERMINATION:

Light affects the growth of plants from the very first time they are exposed to it

The seedling radicle (root) emerges first from the seed, and the shoot appears as the root becomes established. Later, with the growth of the shoot (particularly when it emerges into the light), there is increased secondary root formation and branching. In this coordinated progression of developmental responses are early manifestations of correlative growth phenomena where the root affects the growth of the shoot and vice versa.

SEEDLING DEVELOPMENT:

In the absence of light, plants develop an etiolated growth pattern. Etiolation of the seedling causes it to become elongated, which may facilitate its emerging from the soil.

A seedling that emerges in darkness follows a developmental program known as **skotomorphogenesis (dark development)**, which is characterized by etiolation. Upon exposure to light, the seedling switches rapidly to photomorphogenesis (light development)

Switch from the vegetative to the flowering stage (photoperiodism):

Some plants rely on light signals to determine when to switch from the vegetative to the flowering stage of plant development. This type of photomorphogenesis is known as **photoperiodism** and involves using red photoreceptors (phytochromes) to determine the day length. As a result, photoperiodic plants only start making flowers when the days have reached a "critical daylength," allowing these plants to initiate their flowering period.

LED grow lights can be used as they produce the highest photosynthetically active radiation (PAR) of any light. Also, LEDs require very little power and are rated for between 50000hrs -100,000hrs. PAR designates the spectral range of solar radiation from 400 to 700 nanometers that photosynthetic organisms can use in the process of photosynthesis. This region corresponds with the range of light visible to the human eye.

Plants also detect Photo-Biologically Active Radiation (or PBAR) which is like PAR as it plays a role in the biological processes of plants, but it affects more than just photosynthesis. PBAR designates the wavelength of light between 280nm and 800nm.PBAR is a range of light energy beyond and including PAR.

Adjustable Spectrum LED Grow Lights are used to maximize the efficiency of plant growth and the light emitted (energy usage). By using adjustable spectrum LEDs it’s possible to speed up flowering times, improve the plant’s biochemistry and customize plants’ structure to root better. The LEDs used are COB (Chip on board) LEDs which are the latest and most advanced technology on the market today. An onboard computerized automated production system (codenamed CAPS) controls the quantity of light, the wavelength of light received by each pod and the duration it receives light. The CAPS does this using data from the various sensors present and by using experimental research data on the specific requirement of various aspects of plant growth, it also keeps updating this data by running new incoming data through a neural network.

Light quantity refers to the amount of light a plant requires each day for optimal growth. Light quantity in recent times is expressed in photosynthetic photon flux density (PPFD), in units of $\mu mol/m^2 s^1$.PPFD measures the number of photons that arrive at the plant’s surface each second. The PPFD is measured at various distances with a Full-spectrum Quantum Sensor, also known as a PAR meter.

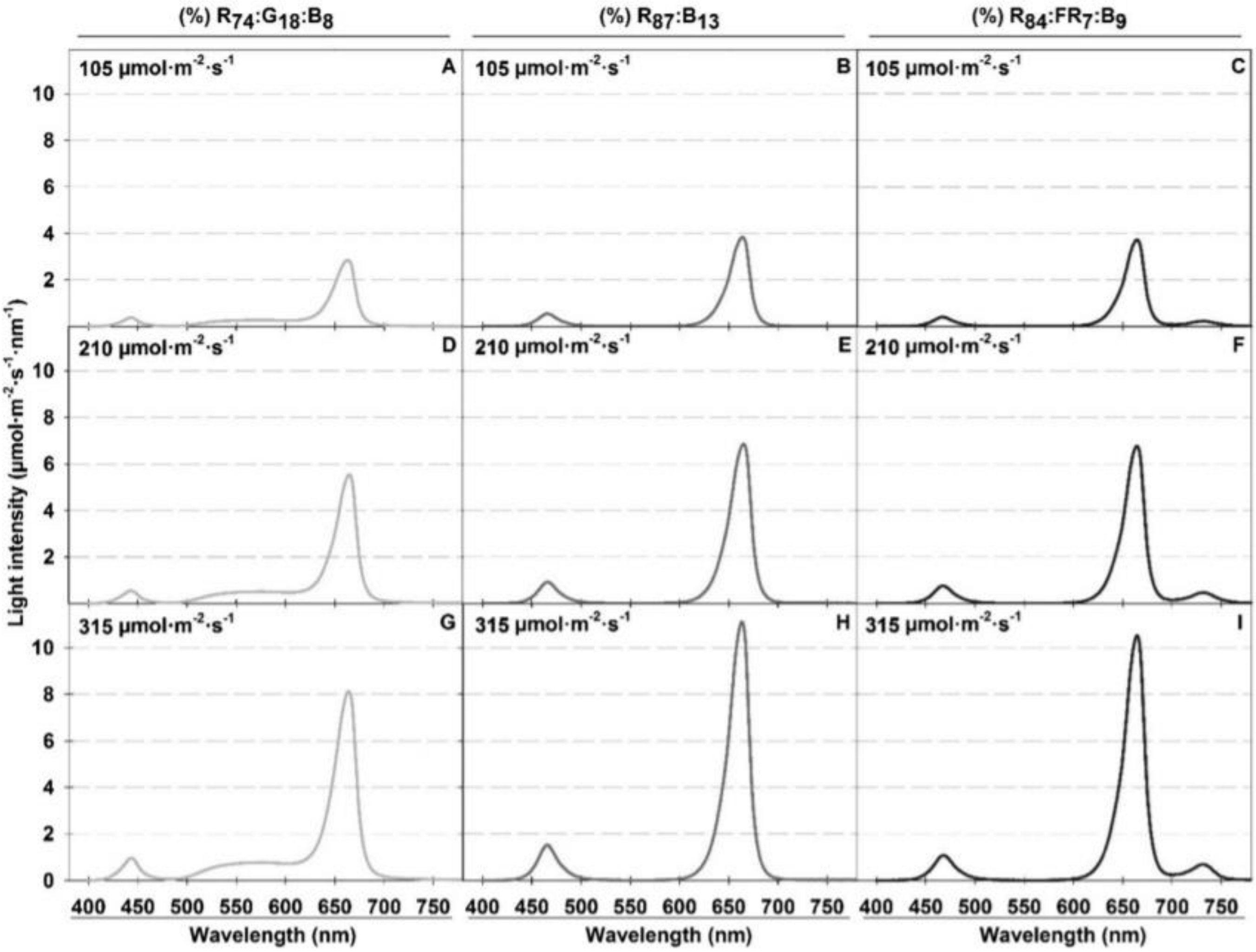
Light Quantity is also measured in daily light integral (DLI). DLI describes the number of photosynthetically active photons (individual particles of light in the 400-700 nm range) that are delivered to a specific area over a 24-hour period. The DLI considers the PPFD and the total number of hours a plant is exposed to that PPFD to get the total quantity of photons per day, in units of $mol /m^2 d^1$ (moles of light per square meter per day).

The relation between PPFD and DLI is as follows:

DLI=PPFD * light hours per day * (3600/1000,000).

PLANT GROWTH DATA

The plants grown on the BIOS-1 are Chinese cabbage, mizuna mustard, red Russian kale, bell peppers, blueberries, and cherry tomatoes.



CHINESE CABBAGE:

Light-6-7 Hrs. Daily | Solution pH: 6.0 to 7.0

PPM – 1700-2000 | pH range 6.0-7.0 for optimal results

EC – 2.5-3.0

PPM -1700-2000

Temperatures 50 F – 70 degrees F Maximum

High Temperatures can destroy the crop

Aeration of Solution and Good airflow essential

6-7 hours of light daily

MIZUNA MUSTARD:

				Mizuna			
105	R_{74}:G_{18}:B_8	4.30 a[y]	1.01	1.88 a	1.19	2.88 a	0.73
	R_{87}:B_{13}	3.88 a	0.96	1.77 a	1.12	2.75 a	0.70
	R_{84}:FR_7:B_9	4.00 a	0.97	1.98 a	1.17	2.89 a	0.71
210	R_{74}:G_{18}:B_8	3.23 b	0.76	1.44 b	0.91	2.17 b	0.58
	R_{87}:B_{13}	3.20 b	0.75	1.42 b	0.89	2.13 b	0.57
	R_{84}:FR_7:B_9	2.58 cd	0.69	1.20 d	0.83	2.15 b	0.54
315	R_{74}:G_{18}:B_8	2.69 c	0.62	1.41 bc	0.78	2.16 b	0.54
	R_{87}:B_{13}	2.56 cd	0.59	1.21 cd	0.74	2.03 bc	0.50
	R_{84}:FR_7:B_9	2.21 d	0.60	1.18 d	0.76	1.89 c	0.48
LQ		***	NS	**	NS	**	**
LI		***	***	***	***	***	***
LQ × LI		**	NS	**	NS	**	NS

				Mizuna		
105	R_{74}:G_{18}:B_8	80.40	8.15	159.98	96.63	51.27 ab
	R_{87}:B_{13}	75.47	7.55	129.14	93.21	54.07 a
	R_{84}:FR_7:B_9	60.06	7.64	127.26	88.73	48.88 abc
210	R_{74}:G_{18}:B_8	58.79	6.69	103.36	73.69	50.41 abc
	R_{87}:B_{13}	62.07	5.76	98.46	74.08	39.62 cde
	R_{84}:FR_7:B_9	46.81	6.14	106.89	70.91	42.15 bcd
315	R_{74}:G_{18}:B_8	53.21	5.69	114.82	63.73	30.66 e
	R_{87}:B_{13}	45.27	5.84	97.48	60.93	35.66 de
	R_{84}:FR_7:B_9	26.09	5.71	80.20	58.87	40.31 bcde
LQ		***	NS	**	NS	NS
LI		***	***	***	***	***
LQ × LI		NS	NS	NS	NS	**

CHERRY TOMATOES:

Lights with specification of 80% red + 20% blue, 95% red + 5% blue, or 100% red are used to grow cherry tomatoes. The recommended DLI for cherry tomato seedling growth ranges from 13 to 16 $mol/m^2 d^1$

RED RUSSIAN KALE:

Light: 6-10 hours daily EC: 1.8–3.0 pH: 6.0–7.5 Temperature: 45–85° F Kale’s wide electrical conductivity (EC) range makes it compatible with many different herbs and greens, though the best growth is seen closer to 3.0. (A basic greens formula will work well for kale.)

BLUEBERRIES:

Light required for 12 to 16 hours daily | Solution pH level - 4.5 to 5.8

PPM- 1260-1360 | Temperature: 22 to 24 degrees Celsius

BELL PEPPERS:

Ideal pH: 5.5-6.5

Target EC: 2.0-2.5

Lights on for 14 to 16 hours daily

Fruits ready for harvest 50 to 80 days post sprouting

1400-1750 PPM

Temp: 65-75 Degrees

Enjoys: Space to grow, good amount of light, high nitrogen, potassium

Bell Peppers will grow 3 – 6 feet tall

POWER

Since BIOS consumes a lot of energy we had to come up with an alternative source of power. we researched thoroughly through the archives of NASA and found that nuclear energy seems like another way to sustain the BIOS. throughout the years, NASA used nuclear fission reactors, radioisotope thermoelectric generator, radioisotope heater unit, multi mission radioisotope thermoelectric generator and many more.

NASA missions included MMRTG in many of its space exploration missions and believes that it can be used either in vacuum of space or within the atmosphere of a particular planet. the excess heat generated from an MMRTG can be used as a convenient and steady source of warmth to maintain proper operating temperatures for a module and its instruments or electrical components in cold environments.

the general-purpose heat source module or GOHS is an important building block for the radioisotope generators used by NASA. these modules contain plutonium-238 (fuel) which gives off heat for producing electricity. these specific units can produce thermal power at 250 watts at the beginning of a mission.

there is another intriguing project created by NASA which is known as the project Kilo Power Reactor. this project is safe, efficient and can provide plentiful energy. the system is a small, lightweight fission power system capable of providing up to 10 kilowatts of electrical power.

the prototype power system uses a solid, cast uranium-235 reactor core. passive sodium heat pipes transfer reactor heat to high efficiency Stirling engines which basically convert the heat to electricity.

hence these power sources can act as our alternative as of now, but we estimate that whole exploration missions will be run by them eventually.

PUMP

A centrifugal pump is used to deliver nutrient rich water to the Hydro-drip system of the BIOS-1. It is the only type of pump tested for space use. The pumps used will be like the ones developed during the COLUMUS program (SAE International). It has many advantages namely long life, noiseless operation, minimum mass, and low energy consumption. Because of its modular design and because of selected materials of multiple compatibility, this pump is well suited for its purpose. Wide speed ranges from about 1,000 to 20,000 rpm which corresponds to a flow from about 1 to 20 1/min, permits an energy saving adaption and flow control. Centrifugal pumps of this kind are already being used in rocket engines.

CRUNCHING THE NUMBERS

The CAPS is the central “managing authority,” the operation code of the BIOS - 1 which manages all inputs, analyzes them, and accordingly acts.

CAPS takes data from multiple PH, temperature, light sensitivity, water level, water constituent, electrical conductivity and IR imaging sensors and matches the same with the CAPS PLANT RESEARCH DATABASE. This database is a collection of records with details on the nutrient, light, water, and other requirements for each plant. When planting, the astronaut registers in CAPS the plant planted in a particular pod which CAPS uses to do this. CAPS uses specialized sensors made to operate in the BIOS - 1’s-controlled environment.

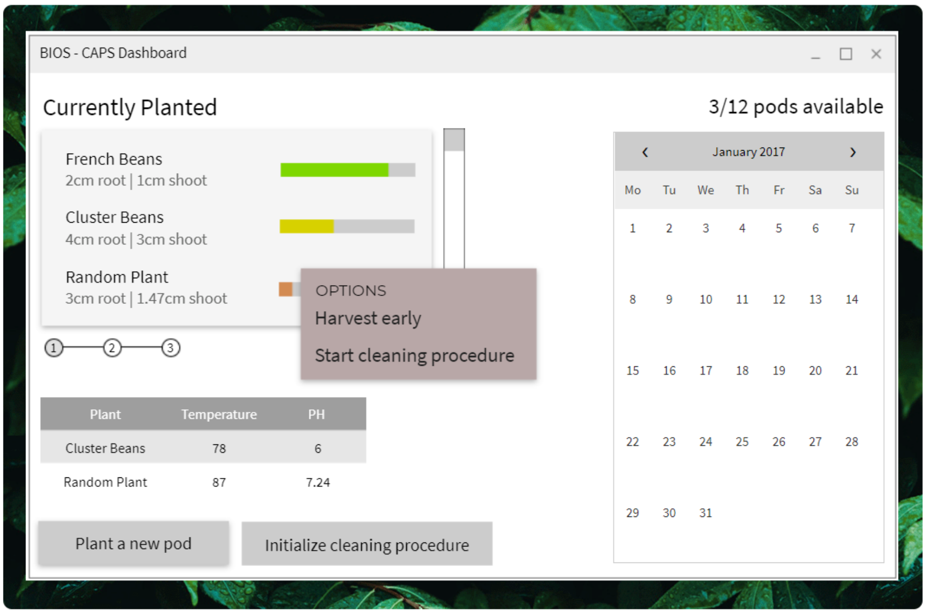
It takes scheduled actions like renewing the water, adding nutrients, managing lights et cetera and automated detection-based actions where it compensates for the lack of a certain thing.

It also serves as the central link which images roots and informs the astronauts of possible harvesting chances.

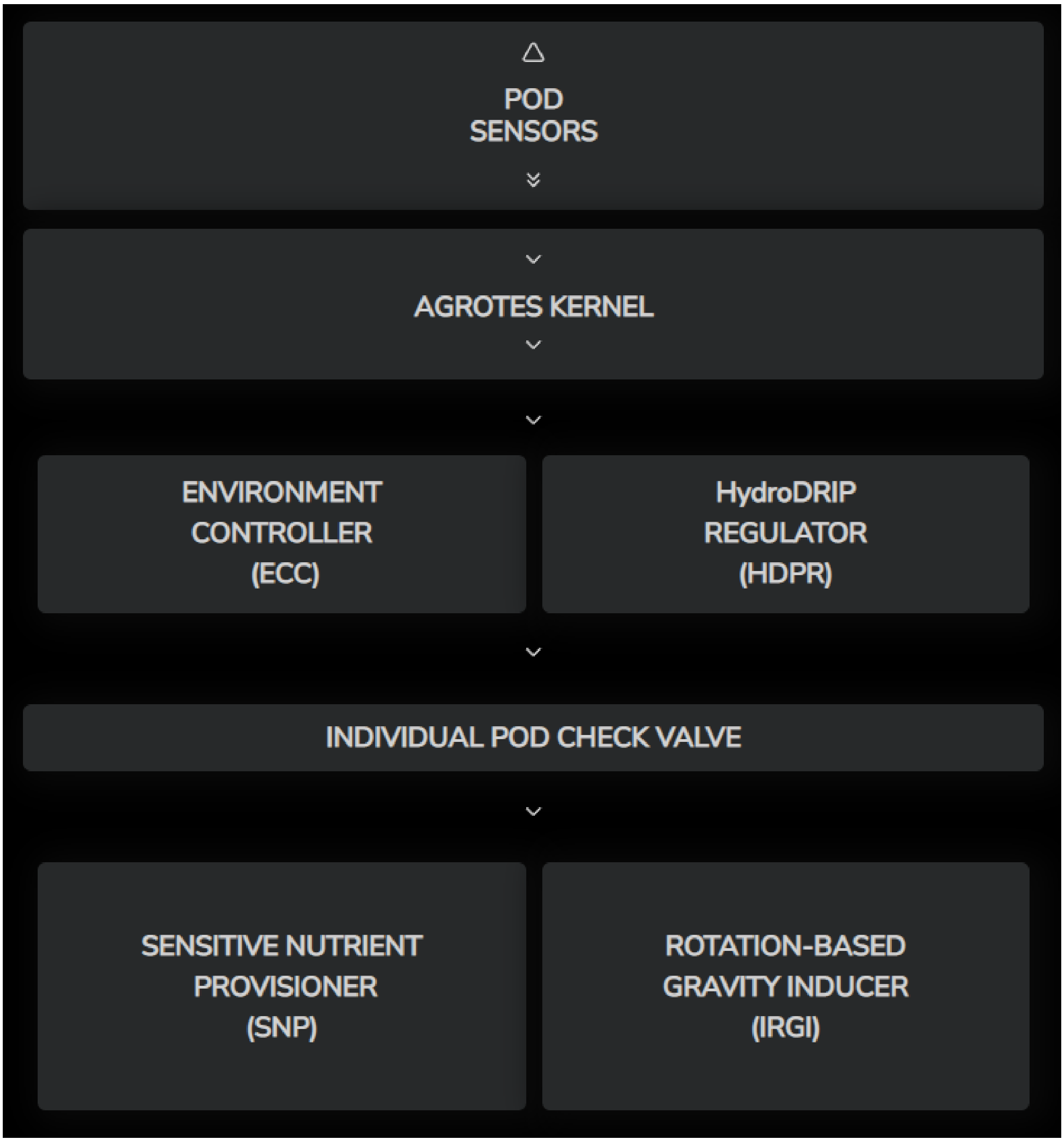
Not only does CAPS take actions, but it passes the same through a neural network each time it does this, to improve itself by learning.

CAPS acts as the “manager” for the ECC (Environment Controller).

CAPS provides a digital display on the surface of the BIOS – 1 to facilitate easy maintenance for the astronauts. The CAPS Dashboard is a neatly arranged visual representation of important highlights of the situation inside the BIOS – 1. The dashboard shows currently planted plants, pod statuses, options to plant a new seed or initialize the cleaning procedure by recycling water, along with sensory datasets. It runs on a custom Arch Linux distribution.
A mock-up UI of the Dashboard has been shown here.



__CAPS LOGIC FLOW:__



The CAPS Sensory Matrix is a network of cross-connected sensors in each pod reporting the following information:
- PH and humidity
- Temperature and light sensitivity
- Electrical conductivity
- Water level and constituents
- IR (root) imaging

Durafet pH Sensor

DURAFET PH ELECTRODE IS AN INDUSTRIAL, NON-GLASS, UNBREAKABLE, ION SENSITIVE FIELD EFFECT TRANSISTOR (ISFET)-BASED PH SENSOR

Pure Water (Low) Conductivity sensors SC4A(J)/SC42

THESE GROUPS OF SENSORS ARE INTENDED FOR LOW CONDUCTIVITY APPLICATIONS FOUND IN WATER AND PHARMACEUTICAL INDUSTRIES.

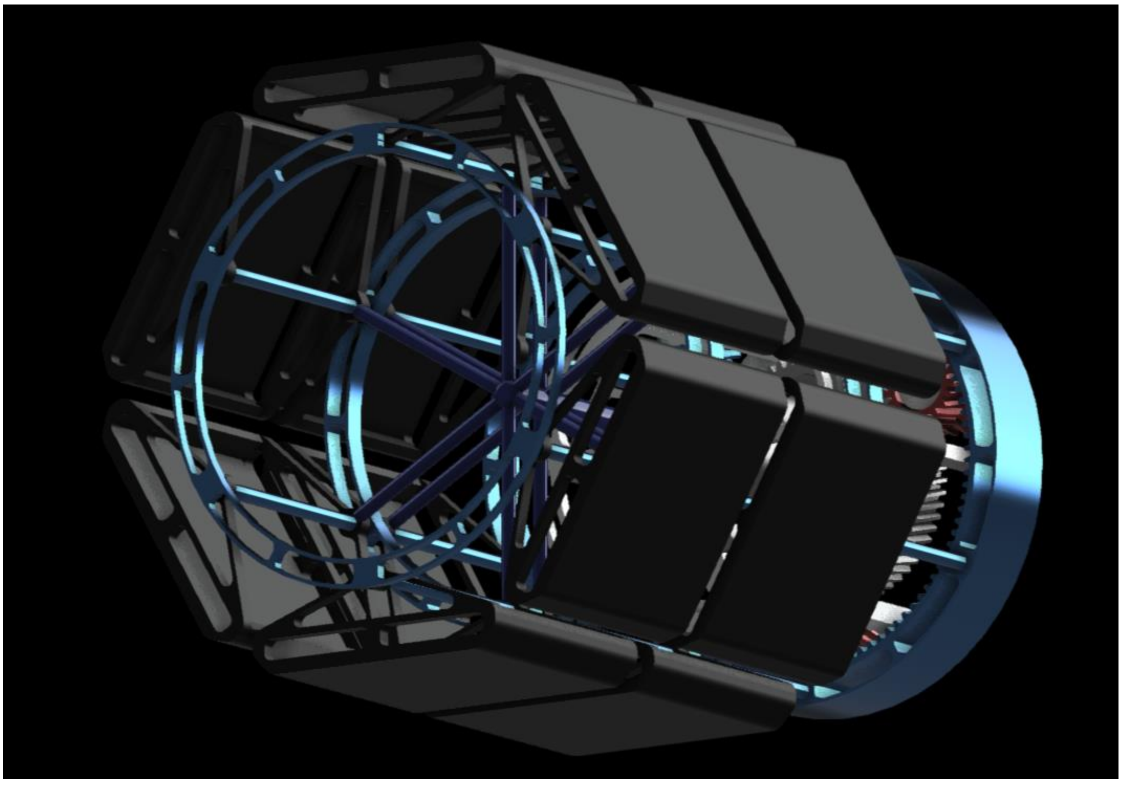
SHARP GL480E00000F

THESE ARE HIGHLY ACCURATE INDUSTRIAL-GRADE IR SENSORS WITH PROVEN RELIABILITY

HydroDRIP PLUMBING SYSTEM

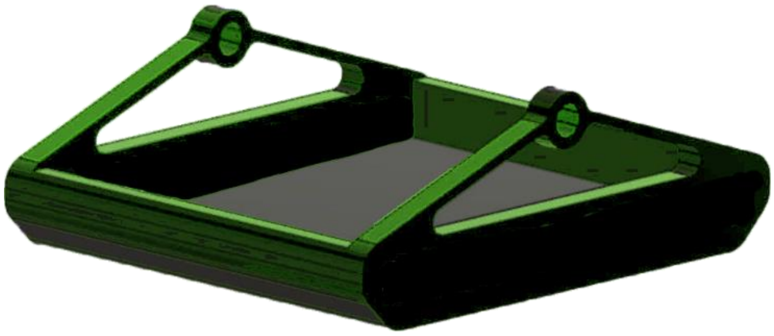
A network of plumbing tubes, the HydroDRIP runs along the wireframe of the BIOS serving as a medium to deploy water and nutrients to each pod.

It is powered by a common central centrifugal pump which is further assisted by individual per-pod check-valves which regulate flow on a granular level.
These check-valves are controlled by 24V solid-state relays in parallel.



PODS

The BIOS Pods host and carry all plants in the system. The 20cm long walls ensure water doesn't flow out, while the 1.8m tall leeway ensures ample space for the shoots to sprout. After days and hours of research, we finally settled on the proper material for the pods. T800 infill, the perfect balance between weight and strength.



LENGTH = 150 cm
BREADTH = 160 cm
AREA = 24000 cm^2
PRODUCTION VOLUME = 4320000 cm^3
WEIGHT PER POD = 147.24 kg

ENVIRONMENT CONTROLLER (ECC)

The BIOS ECC is responsible for acting as and when instructed by the CAPS.
The ECC consists of a nutrient release system, comprising of 6 bottles of various important nutrients which are accordingly measured and released as and when determined by the CAPS.
It also adjusts air pressure, composition, light, and water levels as instructed by the CAPS.
ECC control systems use high power relays to control different systems.
TE Space-grade Electromagnetic & Full-Size Relays
THESE ELECTROMECHANICAL RELAYS AND SOLID-STATE RELAYS ARE SPECIFICALLY ENGINEERED TO OPERATE IN EXTREMELY HARSH ENVIRONMENTS

THERMAL CONTROL LAYER (TRL)

The Thermal Regulation Layer (TRL) is an essential part of the BIOS – 1,
If the outdoor temperature of the BIOS drops beyond a certain point, the TRL initiates its heating cycle.

Across the wireframe of the BIOS are strategically placed heating points which can be used to modulate the inner chamber temperature of the BIOS.

Not only heating, but the BIOS also handles heating due to load processing (example, the CAPS processor and power relays). We do this by employing the existing plumbing mechanism through a heatsink-radiator so that it acts as a water loop and controls the heat with already existing infrastructure.

WATER RECLAMATION

The BIOS has an internal base plate which collects condensed water from the pods.
This water is collected in a small tanker inside the outer chamber.

DIET

Our project aims to provide the Astronauts with nutrients in a long-lasting, easily absorbed form—freshly grown fresh fruits and vegetables while adding fresh food to the astronauts' diet and enhancing happiness and well-being on the space station. In the absence of gravity, plants use other environmental factors, such as light, to orient and guide growth. Right now, astronauts receive regular shipments of a wide variety of freeze-dried and pre-packaged meals to cover their dietary needs – resupply missions keep them freshly stocked on the ISS, but this wouldn't be possible with Mars missions.

When crews venture further into space, traveling for months or years without resupply shipments, the vitamins in pre-packaged form break down over time, which presents a problem for astronaut health. Hence, we plan on growing a variety of plants, including three types of lettuce, Chinese cabbage, mizuna mustard and red Russian kale. We also have peppers, cherry tomatoes as well as a few different types of berries included in our project. All the cultivation will take place hydroponically in a closed and regulated environment. Not only are these foods nutrient-dense and provide a tremendous number of benefits to the astronauts but can also be added to a variety of cuisines.

Kale is a so-called "super food" because of its myriad health benefits. A single serving (one cup) contains more than a day's worth of vitamin A requirement, which is important for eye health and immune function. It is also full of vitamins K, C, and B6 as well as manganese, copper, calcium, and magnesium. Kale is one of the most nutrient dense foods in the world. It is very hydrating and an excellent source of powerful antioxidants.

Like kale, mizuna is low in calories but high in several vitamins and minerals, including vitamins A, C, and K. It is also a good source of Calcium and Iron. This leafy green is particularly high in vitamin A, which is important for maintaining healthy vision and a strong immune system. Like many other cruciferous vegetables, mizuna is a rich source of antioxidants, which protect your cells from damage from unstable molecules called free radicals.

Chinese cabbage provides dietary fiver, calcium, iron, magnesium, phosphorus, potassium, sodium, Vitamin C, K, A and folate. Raw Bok choy contains other vitamins and minerals, including phosphorus, zinc, sodium, copper, manganese, selenium, niacin, folate, choline, beta-carotene, and vitamin K. Cruciferous vegetables, such as Bok choy, are rich in glycosylates. These are sulphur-containing compounds that may benefit human health in a variety of ways.

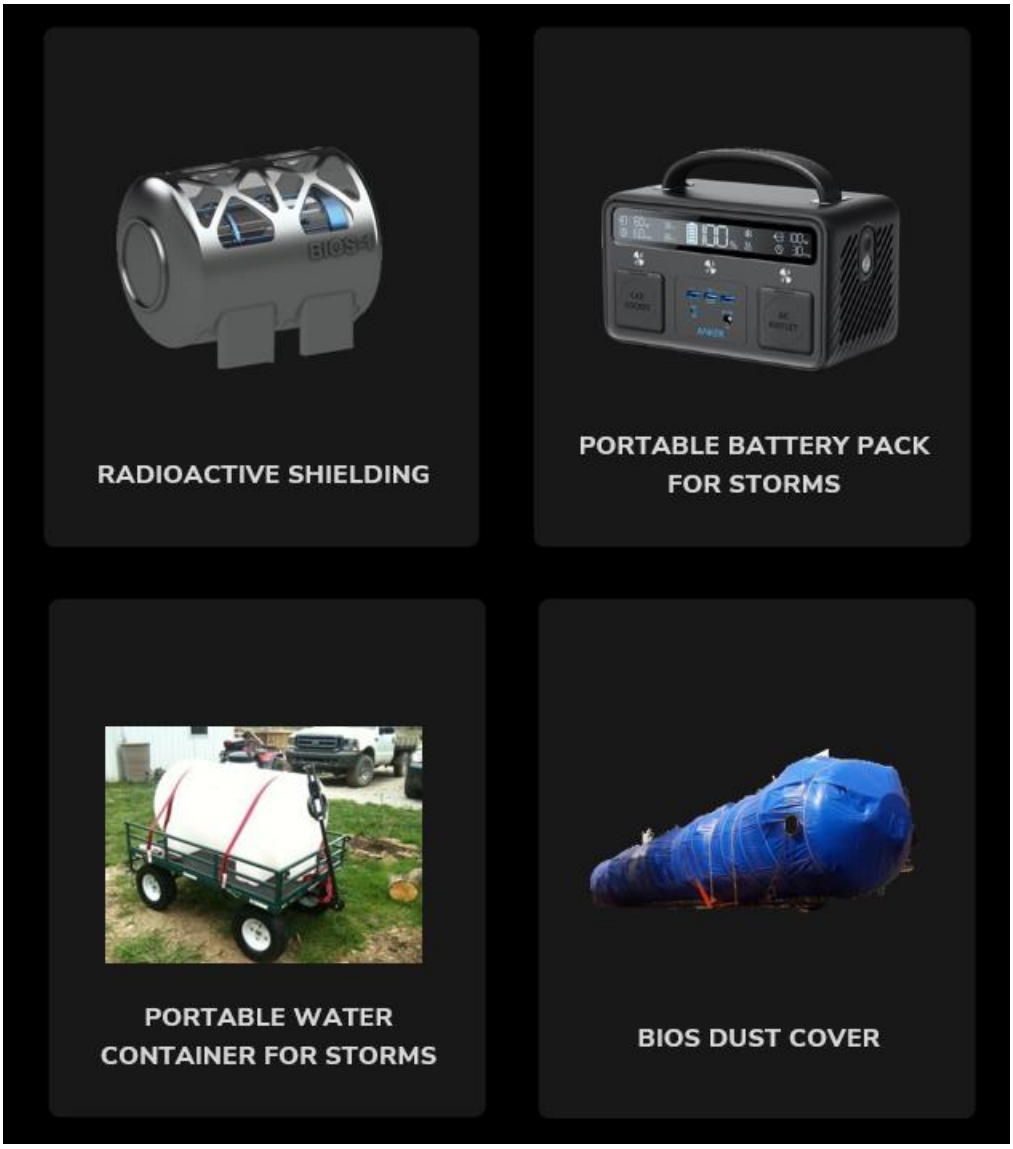
Cherry tomatoes are chock full of vitamins and minerals that promote excellent health. They are packed with vitamin C, which plays a major part in many body functions. The nutrient levels in cherry tomatoes can vary based on when you harvest them, but they can still be an important part of a healthy diet any time of the year. The lycopene in cherry tomatoes may support bone health. A study found that women who consumed tomato products saw lower rates of bone density loss compared to those who consumed less lycopene.

Peppers are low in calories and are loaded with good nutrition. All varieties are excellent sources of vitamins A and C, potassium, folic acid, and fibre. Plus, the spicy ones liven up bland food, making it more satisfying.

We plan on planting blueberries, cranberries and strawberries which will help reduce damage to the astronauts' brain due to cosmic radiation. They are also high in a variety of important vitamins and minerals. Berries included in our plantation system help with space radiation protection and also provide our supplementary plantation system with a sweet taste palette!

ADD-ONS

Optional add-ons depending on deployment scenario.



FUTURE IMPROVEMENTS

- Adopt an aggressive primary role in portable space food production
- BIOS – 2 to be fully autonomous, reducing the already meagre human involvement to none
- Adopting aeroponics for more efficient production
- An in-built composting system
- Reducing design complexity for more efficient mass-production
- Reducing dimensions

CRUNCHING THE NUMBERS

Pod volume	= 0.409 kg/m3
INFILL USED > 20%	
Pod volume with infill	= 0.0818 kg/m3
Material density	= 1800 kg/m3
MATERIAL USED > T800 (TRIBALOY® T-800®)	
Mass per pod	= 147.24 kg
Gravity induced by rotation	= 0.1 * acceleration due to gravity (g)

THE BIOS - 1 ONLY USES 10% OF ACCELERATION DUE TO G TO USE GRAVITROPISM TO ITS ADVANTAGE BY NUDGING THE PLANT ABOUT THE INTENDED GROWTH DIRECTION

Mass for central spine	= 632kg
Estimated water mass	= 2871.36 kg
TOTAL MASS OF THE INTERNAL SYSTEM	= 3503.36kg
Force required in Newtons	= (the total mass * 9.80665) * radius of the arm (2)
	= 162167.472 Nm

Gear system and motor calculations:

DRIVING TEETH	= 60 teeth
SUN TEETH	= 20 teeth
OUTPUT TEETH	= 100 teeth
GEAR RATIO	= 0.6:1
MECHANICAL ADVANTAGE	= 1.67

INPUT RPM	= 11.667 RPM
OUTPUT RPM	= 5 RPM
INPUT TORQUE	= 36457.75
OUTPUT TORQUE	= 64464 Nm
Torque in terms of horsepower	= 59.75
Horsepower in terms of POWER	= 41.97

PLEASE TURN OVER.

TEAM INFORMATION

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