STANDARD SMALL SATELLITE RESEARCH PLATFORM FOR LIFE SCIENCE RESEARCH

Final Demo
Senior Design 2

Group 30
04/20/22

ORGANIZATIONAL CHART

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PROJECT SOLICITATION

- Florida Space Grant Consortium
- NASA Kennedy Space Center
- Development of a standard Small Satellite (e.g. CubeSat range) platform for Life Sciences research
- Usage of interchangeable research modules usable on Earth, in Low Earth Object, lunar orbit, aboard a lunar outpost (e.g. Gateway), and on the Lunar surface

PROJECT TECHNICAL GAPS

Goal	Category	Gap	Sub-gap	Description
Main	Hardware	Environmental Monitoring	Root Zone Sensors	Lack of effective Root Zone Moisture Sensor
Stretch	Crops	Crop Performance	Yield Database	Incomplete data sets on yield of candidate crops in space environments

GOALS AND OBJECTIVES

Mission:

Our mission is to design an environmental monitoring system for plants in microgravity (Lunar Orbit) and tackle NASA Technical Gaps.

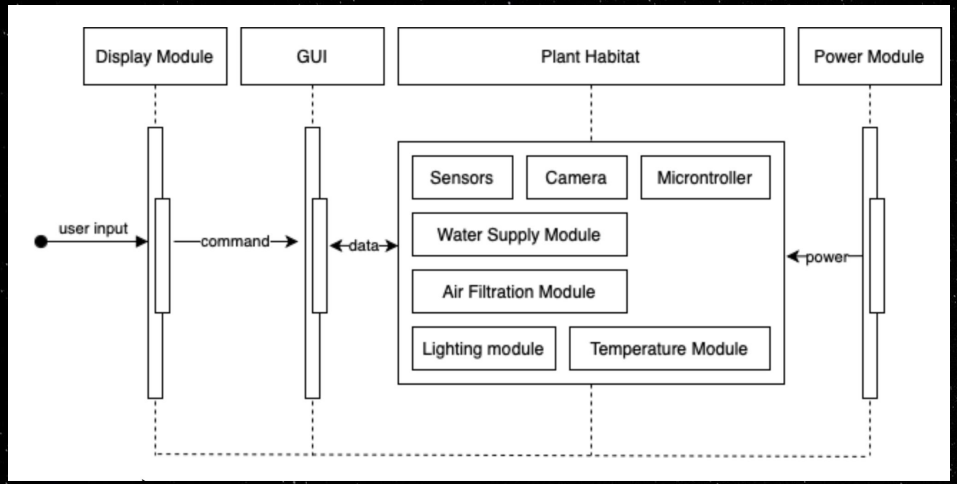
Objectives:

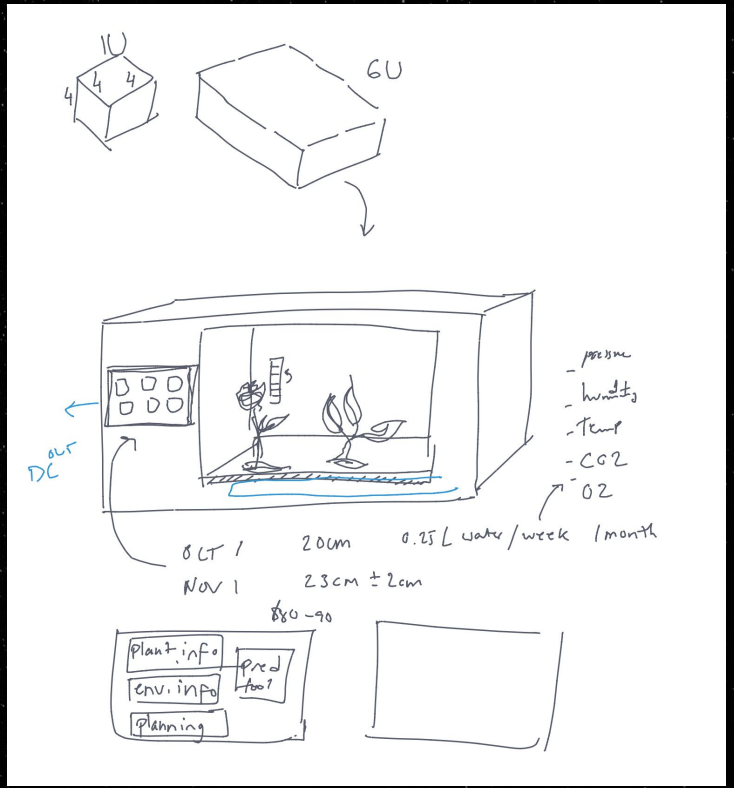
- The data will successfully be gathered and transferred to the database from the humidity sensor, temperature sensor, light sensor, and camera units.
- The web app will display the sensor information and images of the plant outlining ideal conditions for plant growth.

INTERVIEWS CONDUCTED

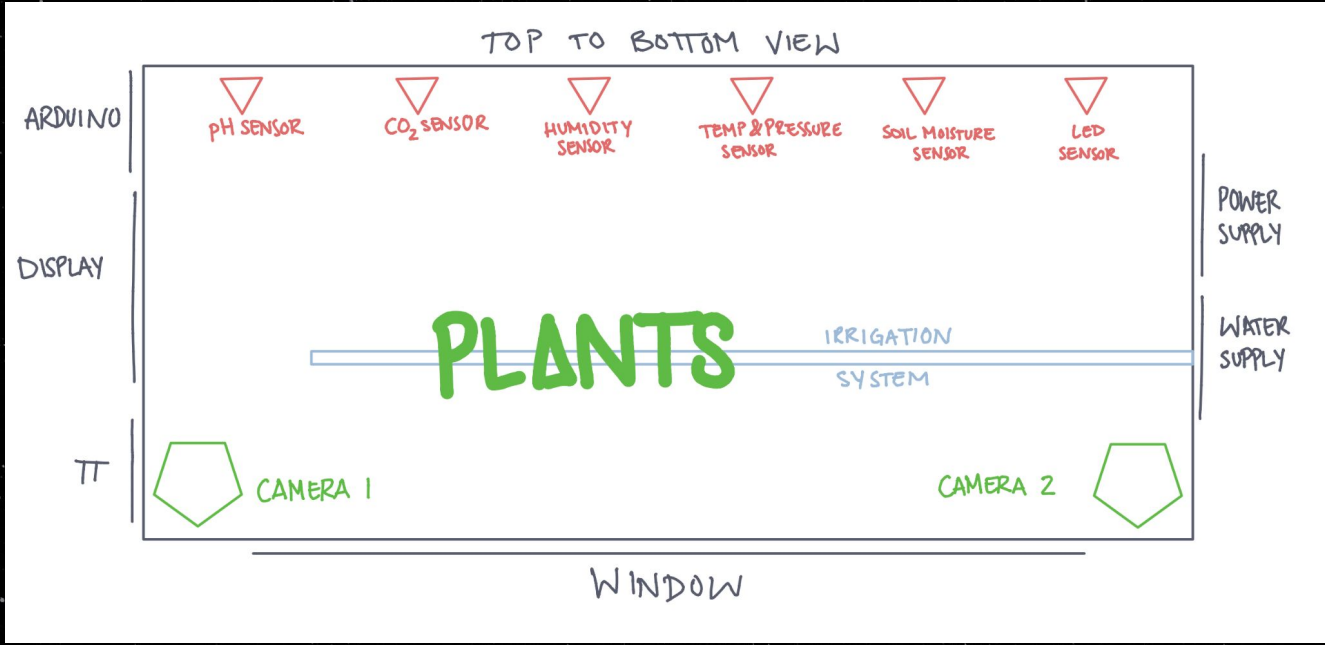
Name	Background	Discussion
Dr. Allen	UCF MAE Department	CubeSat structure
Dr. Colwell	UCF Physics Department	CubeSat feasibility
Karen Debaere	UCF Biology Department	Tissue culture
Stephen Dick	UCF System Administrator	Communication and antennas
Dr. Mason	Plant Physiology	Plant research
Dr. Massa	NASA KSC Horticulture	Plants in space
Dr. Nunez	NASA KSC Flight Technologies	Systems Engineering
Julia Walton	Biology Laboratory	Sterilization and labs

SYSTEM ARCHITECTURE

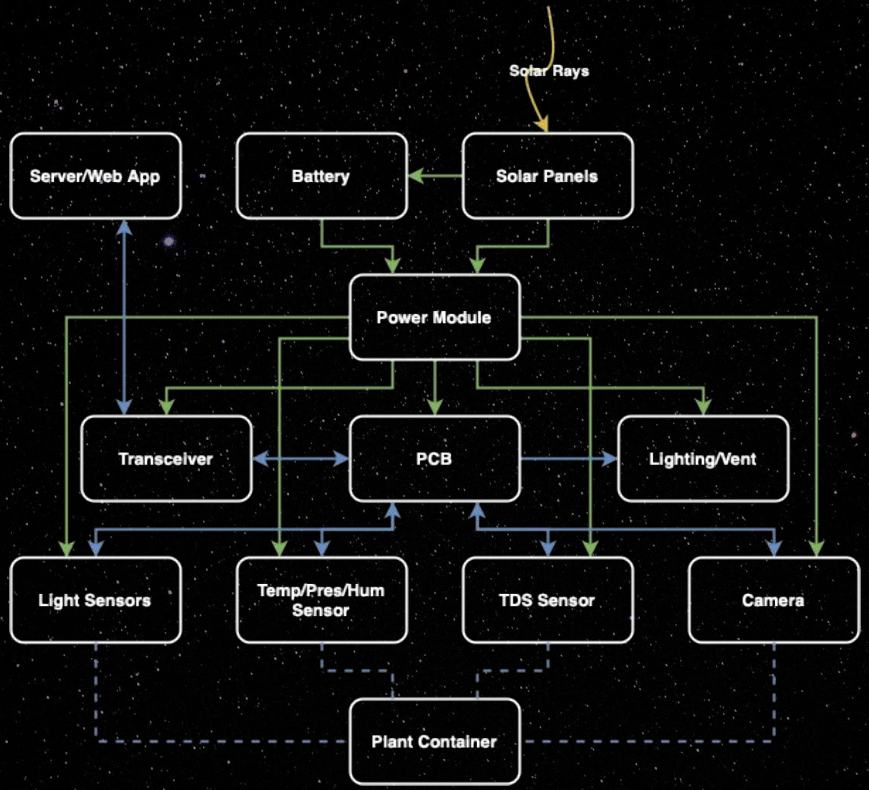




SYSTEM ARCHITECTURE

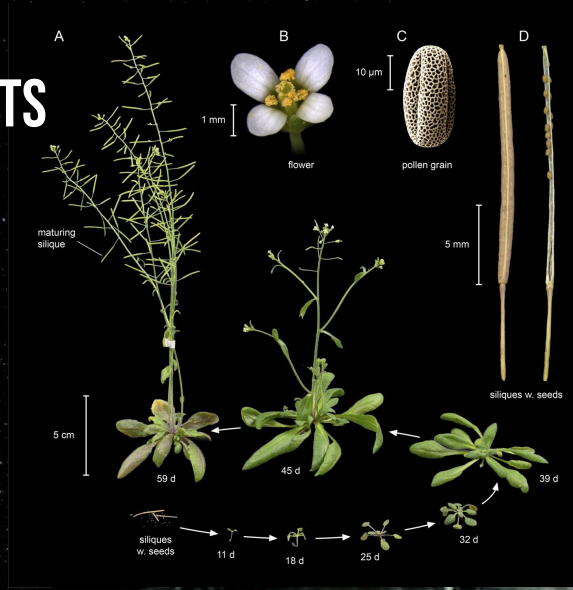


SYSTEM ARCHITECTURE



ARABIDOPSIS THALIANA SPECIFICATIONS AND REQUIREMENTS

Aspect	Description
Grown Size	~ 2-3 centimeters in diameter
Life Cycle	Short life cycle about 6-8 weeks from germination to seed maturation
Grown Mass	~ 2.5 grams
Watering frequency	Sealed container retains moisture sufficient for operational period
Photoperiod	16:8



NICOTIANA TABACUM SPECIFICATIONS AND REQUIREMENTS

Aspect	Description
Photoperiod	18:6
Germination	7-10 days
Temperature	20-25 degrees C
Watering frequency	Sealed container retains moisture sufficient for operational period
Growth medium	Murashige and Skoog
Weeks since planted	7 weeks by recording 8 weeks by final presentation

HARDWARE SPECIFICATIONS AND REQUIREMENTS

- Dimensions: 6U (20cm x 10cm x 34.05cm)
- Camera: 720p-1080p, Images taken to be processed by server
- Temperature: ±1.0°C accuracy
- Humidity: ±3% accuracy
- Pressure: ±1 meter or better accuracy
- Light Sensor:IR 550nm-1000nm (centered on 800), Visible 400nm-800nm (centered on 530)
- Spectral Color Sensor: able to detect not only the amount of light present, but also the amounts of light within 400nm - Near IR wavelengths

PAYLOAD SPECIFICATIONS

- Review on small cube sizes:
  - 1U CubeSat is 10 cm × 10 cm × 11.35 cm.
  - **6U CubeSat is 20 cm × 10 cm × 34.05 cm.**
  - 12U CubeSat is 20 cm × 20 cm × 34.05 cm.
  - Smallest existing CubeSat design is 0.25U and largest is 27U.
- Payload Dimensions: 6U (9.7 x 19.7 x 22.3cm)
- Research shows that:
  - Payload mass- 7.2-7.8 kg (configuration dependent)
  - Available Payload volume 97 x 197 x 223 mm3
- Box is laser cut 0.25 plywood(10 x 15 x 20 cm)

CAMERA SELECTION

	ArduCAM Mini (2MP)	ESP32-CAM (2MP)	IMX219 (8MP)
Image Resolution	1600 x 1200	1600 x 1200	3280 x 2464
Interface	I2C/SPI	I2C/SPI	I2C
Voltage	3.3V - 5.0 V	3.3V - 5.0V	3.3V
Price	$25.99	2 for $17.99	$27.99

ENVIRONMENTAL SENSOR SELECTION

	BME280	MPL115A2	DS18B20
Interface	I2C/SPI	I2C	1-Wire protocol
Voltage	1.8V - 5.0V	3.0V - 5.0V	3V - 5.5V
Accuracy (temp., humidity, pressure)	±1°C,±3% ,±1 meter	±1°C, no humidity,±0.1	±0.5°C, no pressure, no humidity
Price	$11.99	$9.95	$9.99

LIGHT/SPECTRAL COLOR SENSOR SELECTION

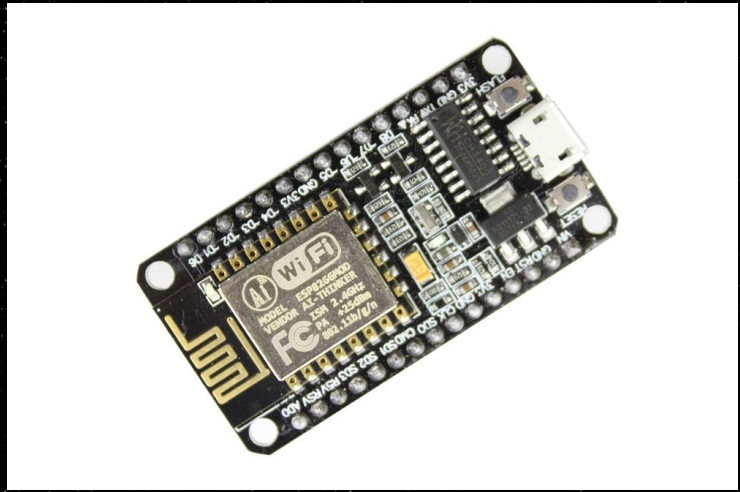
	AS7341	SI1145	TSL2591
Interface	I2C	I2C	I2C
Voltage	3.3V - 5.0V	3.0V - 5.0V	3.3V - 5.0V
Operating Range	IR, Visible Spectrum (8 channels)	IR, Visible Spectrum	IR, Visible Spectrum
Price	$25.79	$15.99	$8.95

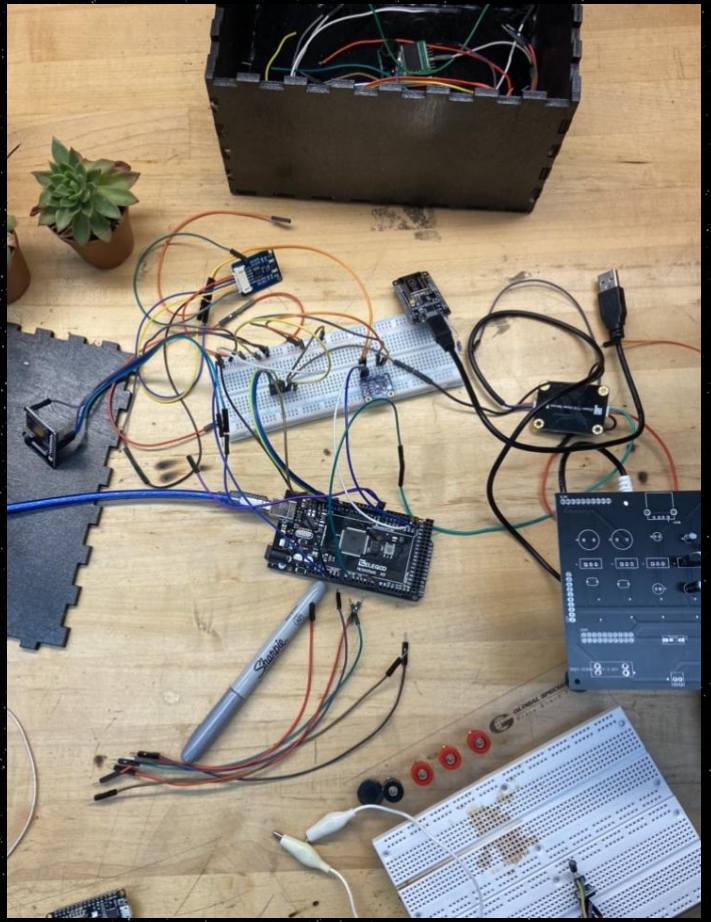
LIGHTING MODULE SELECTION

	WS2812 LED Matrix	WS2811 LED Strip	TRYSOMDIO Grow Lights
Voltage	5V	5V	5V
Addressable LEDs?	Yes	Yes	No
Size	3.15 in x 3.15 in	3.2 ft	12.87 in x 6.77 in x 3.3 in
Price	$11.99	$9.99	$21.99

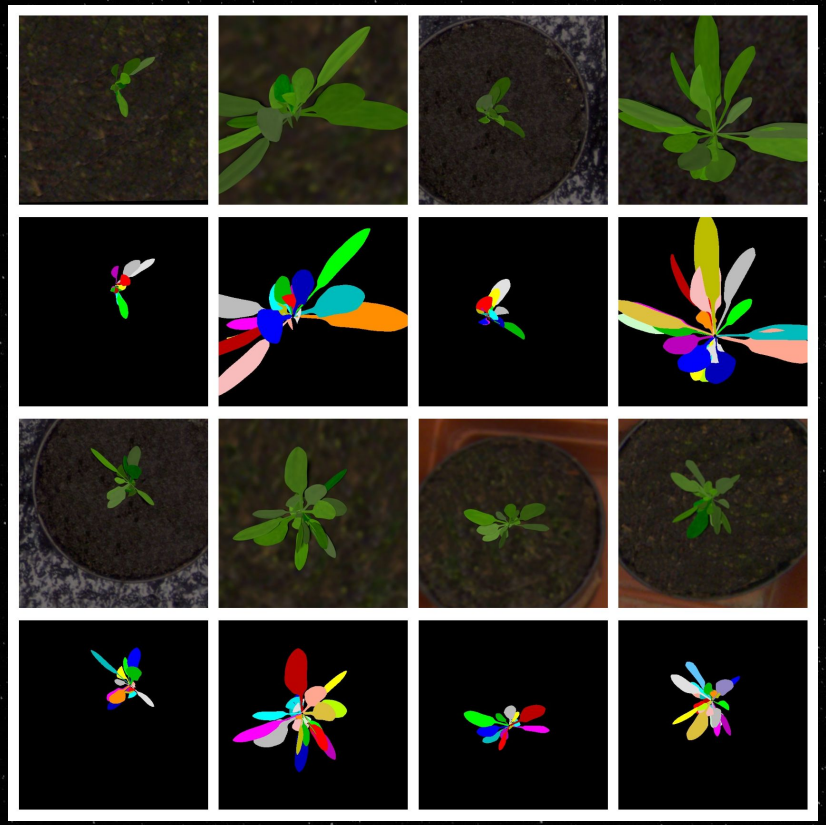
WIFI MICROCONTROLLER - ESP8266

- Allows wireless transfer of data to our server
- Full WiFi front-end (client/access point)
- TCP/IP stack with DNS support
- Antenna trace: 2.4 GHz

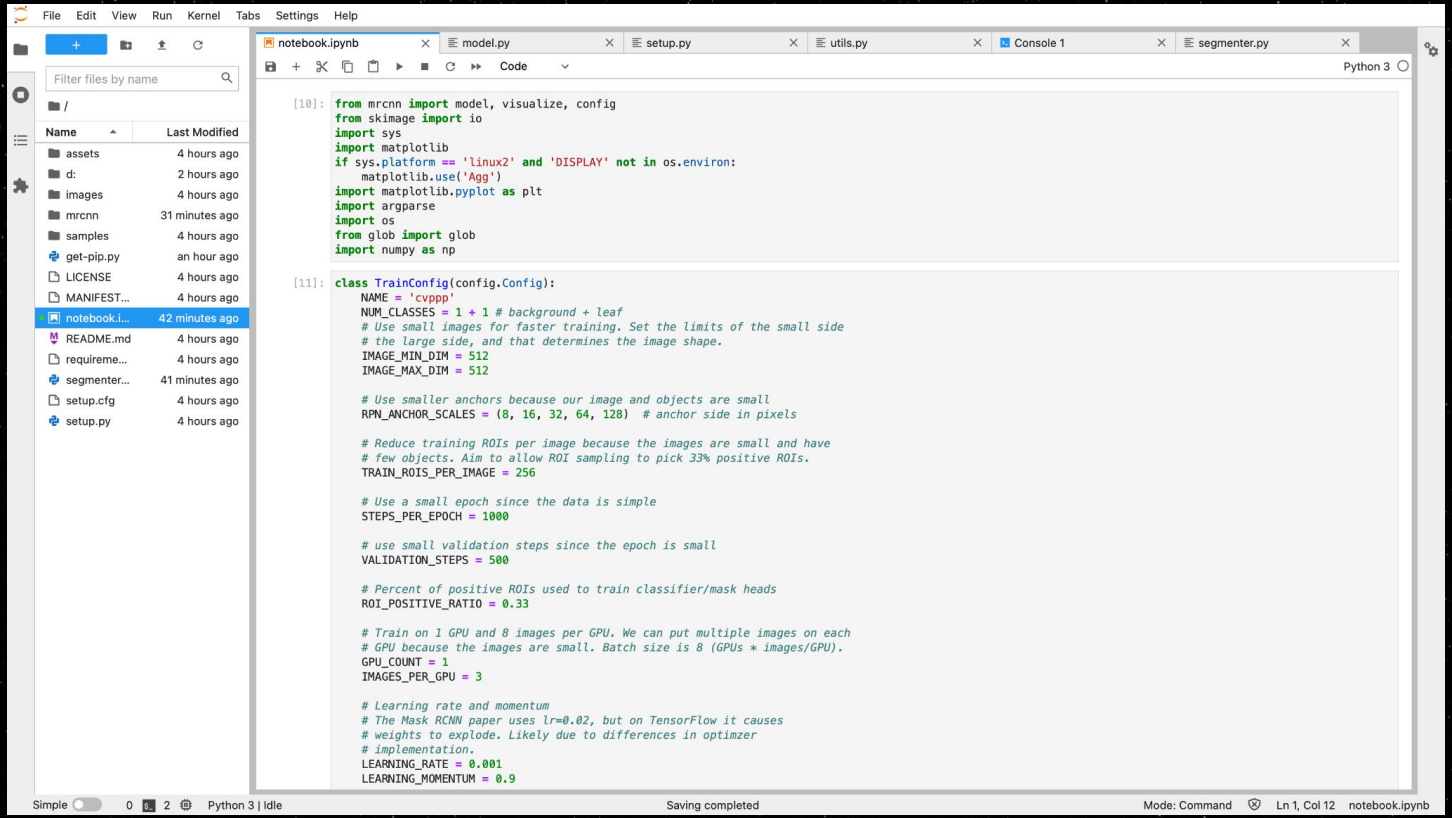




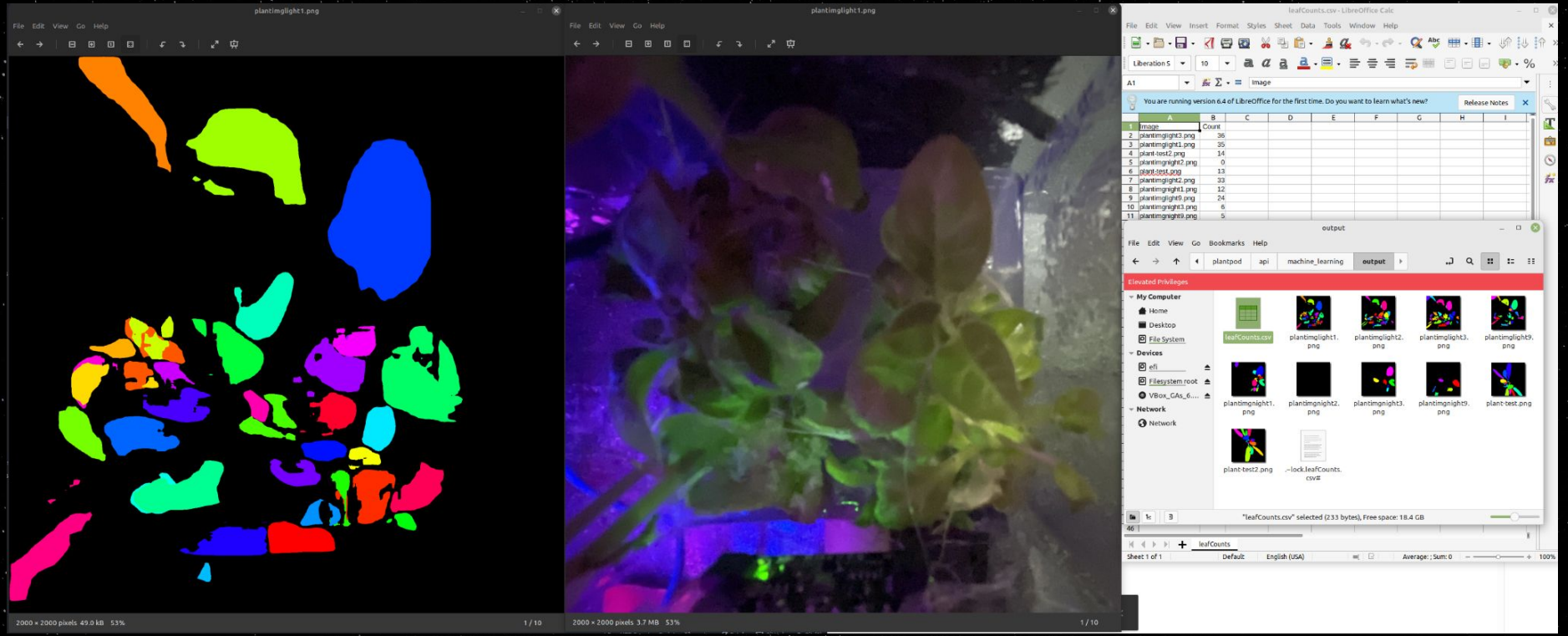
MACHINE LEARNING RAW AND LABELED IMAGES



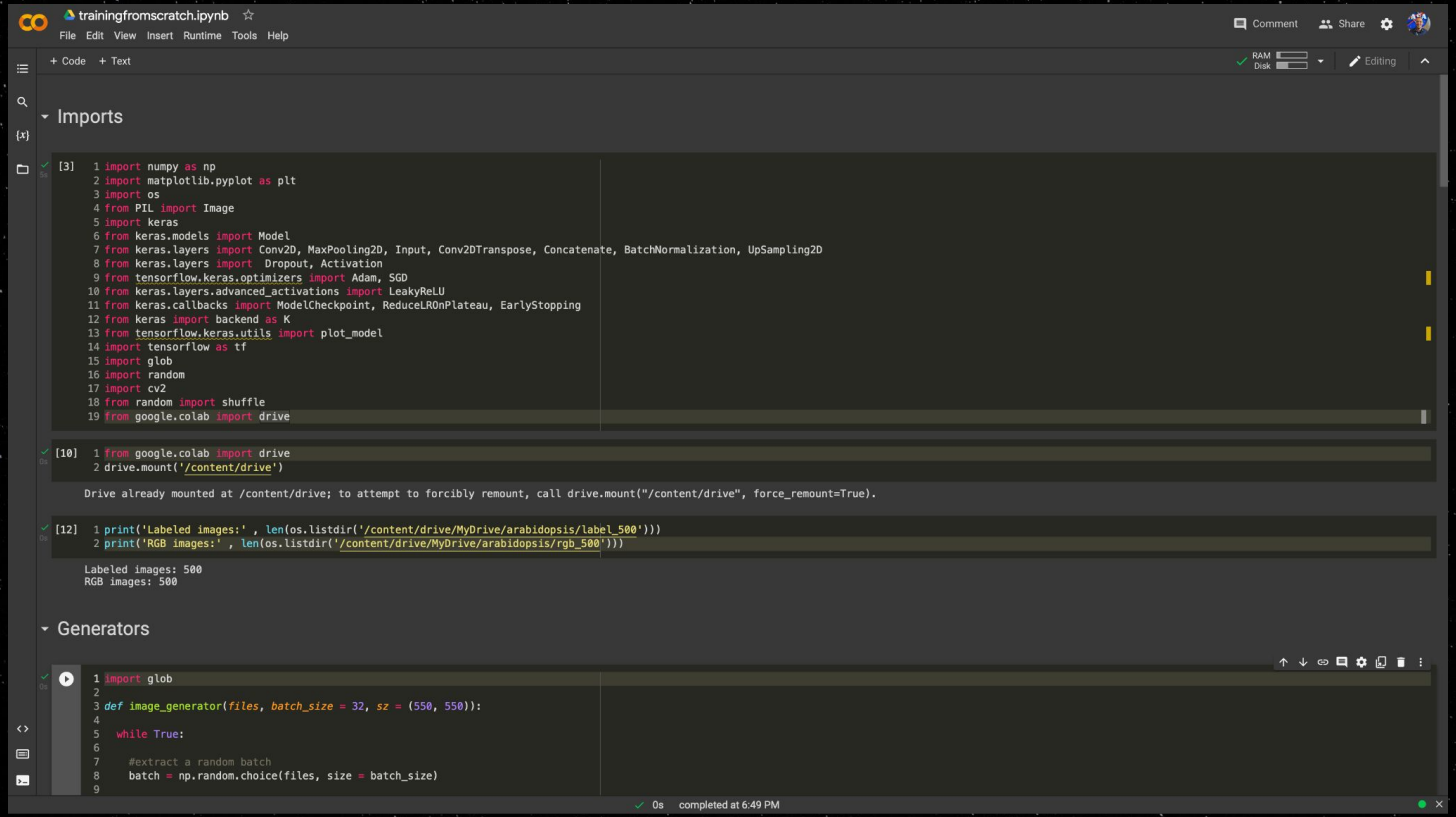
MACHINE LEARNING JUPYTER NOTEBOOK



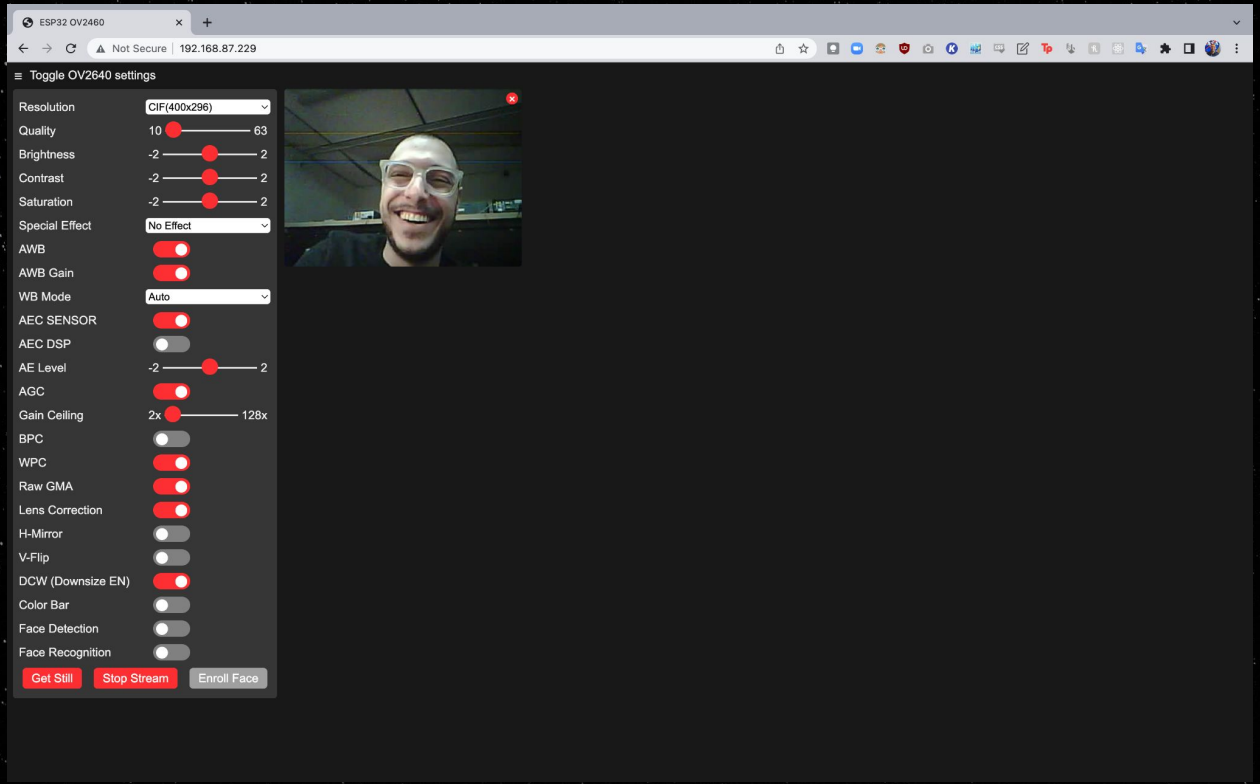
INSTANCE SEGMENTATION ON SERVER



COMPARISON MODEL USING U-NET



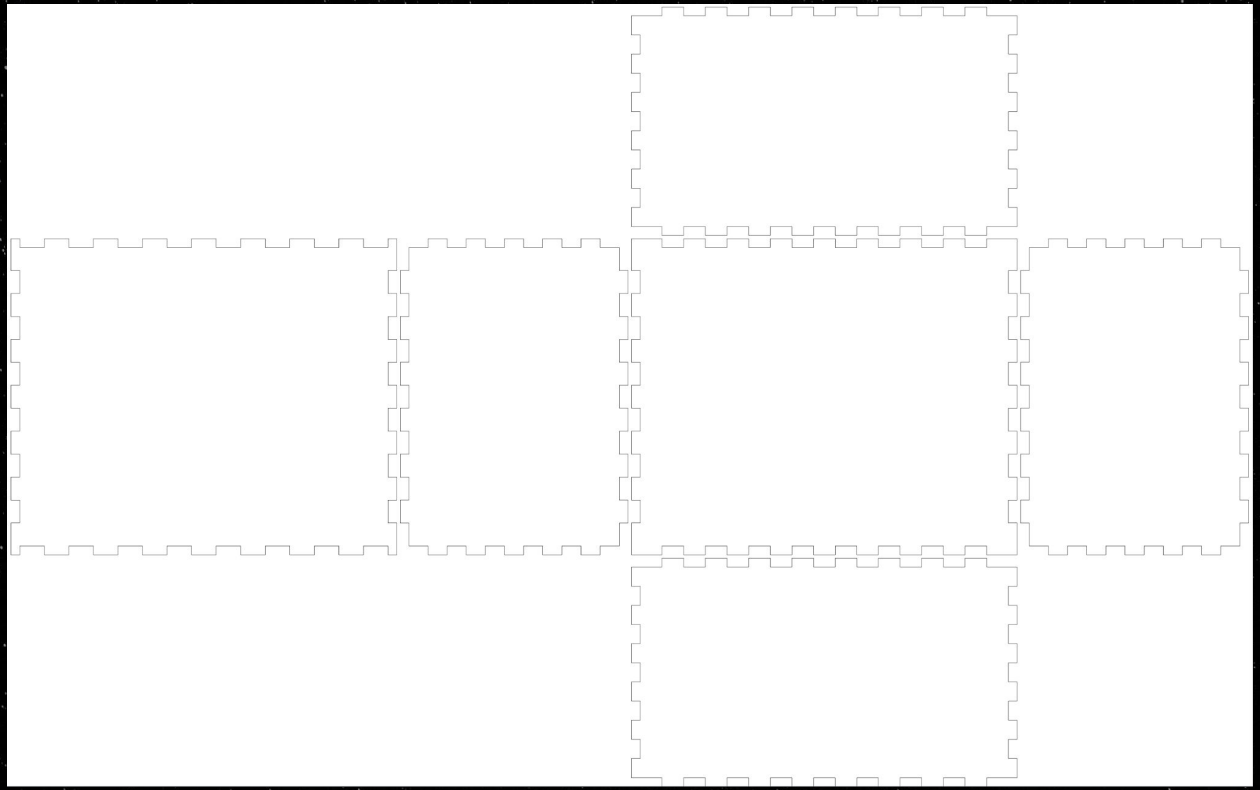
CAMERA TESTING



SYSTEM DESIGN

PAYLOAD DESIGN ON FUSION 360

PAYLOAD DESIGN



POWER REQUIREMENTS

Designing a power budget:

The budget is determined by orbit, efficiency of the photovoltaic cells.

Evaluation can be simulated using tools like orbit simulators such as Systems tool kit(STK). This tool is also useful for communication simulations for satellites.

Between this and data supplied by cubesat vendors

Other Subsystems will require power that are necessary for space flight

POWER DESIGN

Electrical Power Systems

Given Estimated Power Production

- 19.2 watts per panel
- 38.4 watts

Estimated Average Payload Power Available

- 10-30 W
- 3.3V, 5V outputs

POWER SUPPLY

Because the system is a research platform we ended up using a

external power supply using a 2.1mm power jack.

A variable power supply was ordered to provide the system a range of voltages for testing and system testing of the research platform.

Universal Power Adapter 4V 5V 6V 9V 12V 15V 18V 19V 20V 24V Adjustable Switching Power Supply.

The system can also be run on a external 12v battery if ground

testing requires.

MCU SELECTION

Item	Description	Price
atmega2560	16 MIPS and operates at 16 MHz with 256 kBytes flash memory	$15.67
atmega168	20 MHz and 16KBytes of In-System Self-Programmable Flash program	$4.77
MSP430	24-MHz clock and features 32KB of embedded FRAM	$15.59

Several factors in determining the appropriate microcontroller for this project.

Cost and capacity.

Can it store camera data and is their support?

There was only one choice choice is obvious among these options.

ATMEGA2560

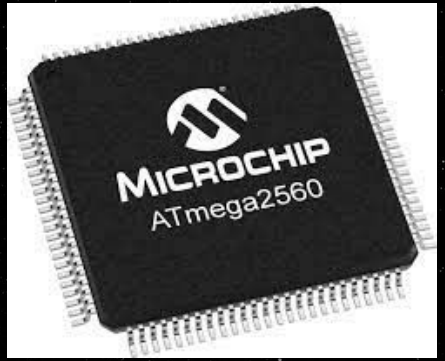
-Is a low-power microcontroller that operates between 4.5 and 5.5 volts

-Capable of 16 MIPS and operates at 16 MHz using an external crystal oscillator.

-100 pins with 86 general purpose I/O lines

-16 10-bit A/D converter

-Operating temp -40 - 85



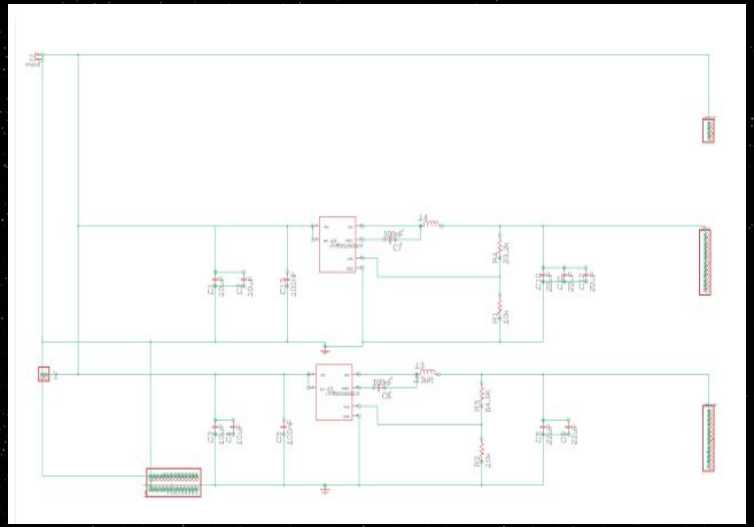
HARDWARE DESIGN (ORIGINAL)

Voltage Converter:

12V to 3.30V @ 3 (TPS56339)

Efficiency: 89.8%

Topology: synchronous switching step-down(Buck)



12v to 5.00V @ 5A using (TSP565208)

Efficiency: 94.3%

Topology: synchronous switching step-down(Buck)

HARDWARE DESIGN

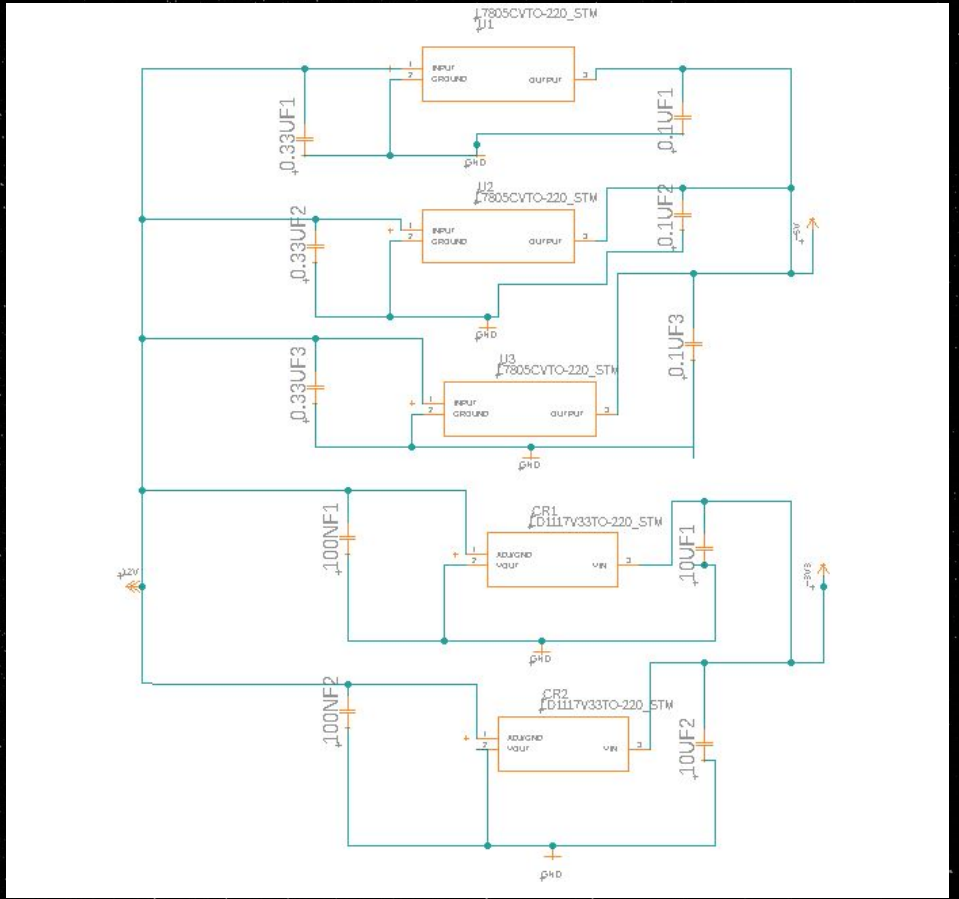
Voltage Converter:

12V to 3.30V @ 800mA each

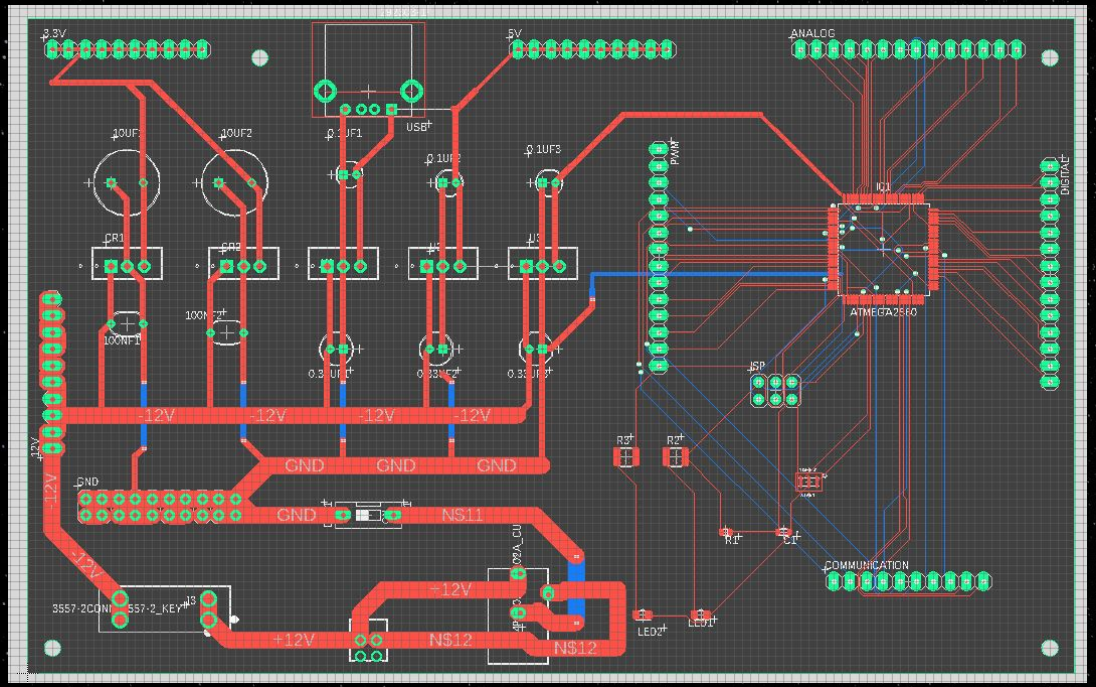
Topology: linear Voltage Regulator

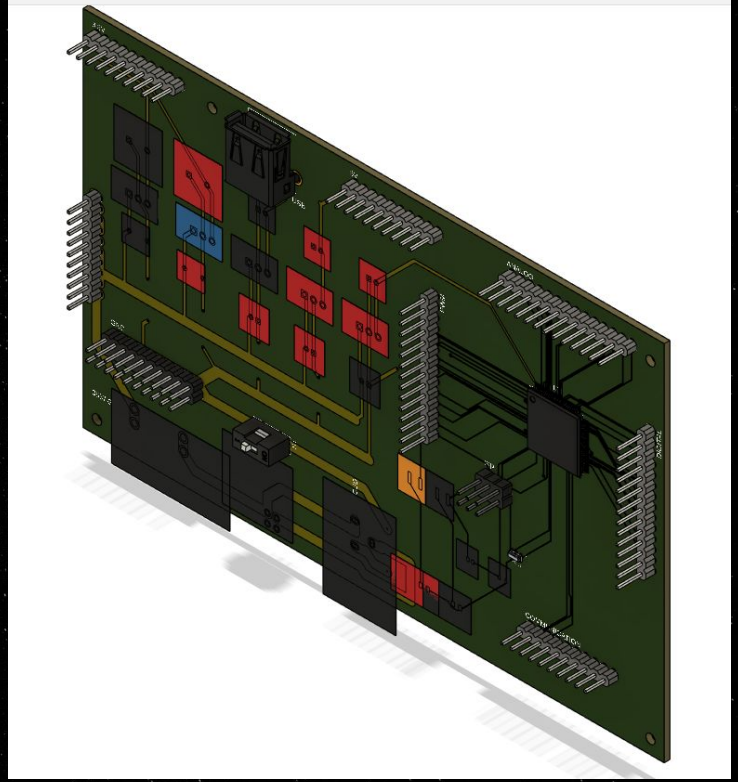
12v to 5.00V @ 1.5A each

Topology: linear Voltage Regulator



HARDWARE DESIGN





ARDUINO IDE

Arduino Integrated Development Environment - or Arduino Software (IDE) -

It contains a text editor for writing code, a message area and it connects to the Arduino hardware to upload programs and communicate with them.

Many of the sensors have libraries on github that allowed for simple integration with the arduino platform.

ARDUINOJSON

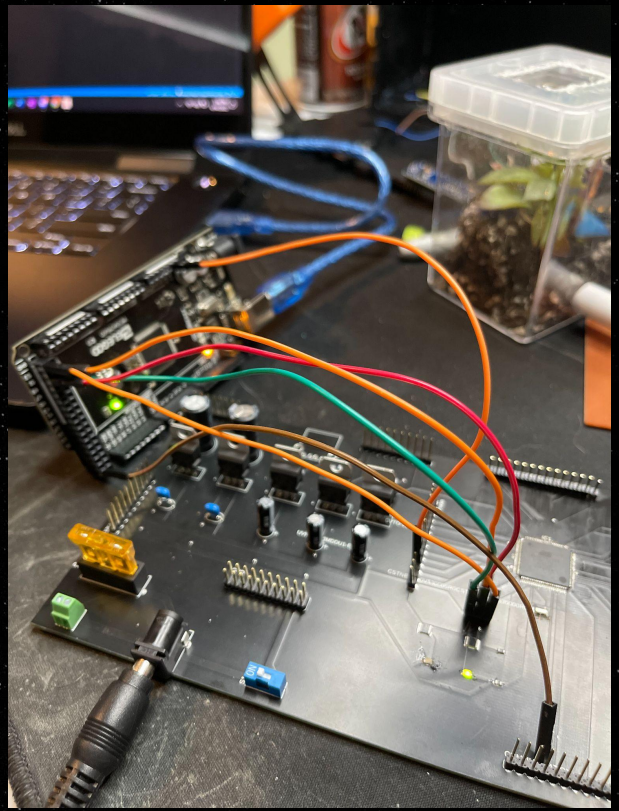
ArduinoJson is on of the best libraries that allows for the serialization and transfer of data to the ESP transceiver module and then on send to the server.

This was also useful for the parsing of data when it came time to display data on the server side.

PROGRAMMING THE ATMEGA 2560

Using ISP (AKA. ICSP) Arduino platform comes integrated with the ability to use its development boards as programmers for any of its supported chips.

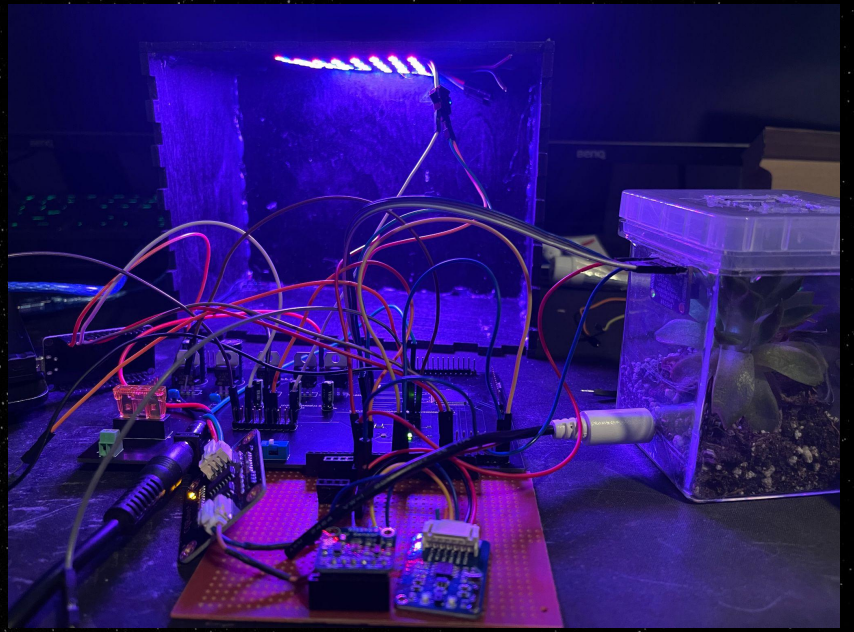
Future integration of a usb for communication was determined to beneficial because the space constraints for plugging in programing leads.



LESSONS LEARNED

Proper connectors would be beneficial to avoid the loose connection and issues associated with that. Or in the case of this system integrated circuit boards with leads to the sensors used. This relies on the fact is the entire system can not iterate easily.

The Arduino platform is great for initial development but a Real-Time operating system for timing actions of sensors and sending data. This will reduce power consumption for some components being in an always on state.



MACHINE LEARNING SPECIFICATIONS AND REQUIREMENTS

- Analyze pretrained model: Mask R-CNN using Synthetic Arabidopsis Dataset
  - Dataset size: 10,000 images
  - Images (width × height): 550×550 pixels
  - Output: instance segmentation
- Train new model: YOLOv5/U-NET using Synthetic Arabidopsis Dataset
  - Dataset size: 10,000 images
  - Images (width x height): 550×550 pixels
  - Output: instance segmentation
- Compare models
  - Accuracy of YOLOv5/U-NET to Mask R-CNN

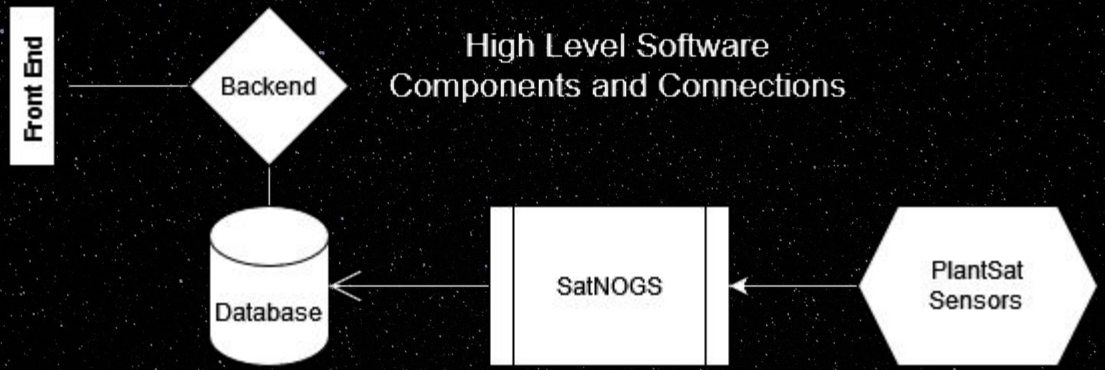
MACHINE LEARNING REMOTE SERVER

```
root@PlantPodServer:~/plantpod/api/machine_learning# sudo python3 segmenter.py --inputImage './plant-test.png' --weightsPath ./leafSegmenter0005.h5 --useCPU
Using TensorFlow backend.
2022-03-22 20:20:45.656430: W tensorflow/stream_executor/platform/default/dso_loader.cc:55] Could not load dynamic library 'libcuda.so.1'; dlerror: libcuda.so.1: cannot open shared object f
ile: No such file or directory
2022-03-22 20:20:45.656666: E tensorflow/stream_executor/cuda/cuda_driver.cc:313] failed call to cuInit: UNKNOWN ERROR (303)
2022-03-22 20:20:45.656773: I tensorflow/stream_executor/cuda/cuda_diagnostics.cc:156] kernel driver does not appear to be running on this host (PlantPodServer): /proc/driver/nvidia/version
 does not exist
2022-03-22 20:20:45.657183: I tensorflow/core/platform/cpu_feature_guard.cc:143] Your CPU supports instructions that this TensorFlow binary was not compiled to use: AVX2 FMA
2022-03-22 20:20:45.670496: I tensorflow/core/platform/profile_utils/cpu_utils.cc:102] CPU Frequency: 2494085000 Hz
2022-03-22 20:20:45.670893: I tensorflow/compiler/xla/service/service.cc:168] XLA service 0x7fca24000b60 initialized for platform Host (this does not guarantee that XLA will be used). Devic
es:
2022-03-22 20:20:45.671014: I tensorflow/compiler/xla/service/service.cc:176]   StreamExecutor device (0): Host, Default Version
2022-03-22 20:20:48.958220: W tensorflow/core/framework/cpu_allocator_impl.cc:81] Allocation of 51380224 exceeds 10% of free system memory.
2022-03-22 20:20:49.095825: W tensorflow/core/framework/cpu_allocator_impl.cc:81] Allocation of 51380224 exceeds 10% of free system memory.
2022-03-22 20:20:49.149676: W tensorflow/core/framework/cpu_allocator_impl.cc:81] Allocation of 51380224 exceeds 10% of free system memory.
2022-03-22 20:20:51.004048: W tensorflow/core/framework/cpu_allocator_impl.cc:81] Allocation of 51380224 exceeds 10% of free system memory.
2022-03-22 20:20:58.049938: W tensorflow/core/framework/cpu_allocator_impl.cc:81] Allocation of 33554432 exceeds 10% of free system memory.
RESULTS!!!!!!!!!!!!! >>>14
root@PlantPodServer:~/plantpod/api/machine_learning#
```

MACHINE LEARNING UCF SERVER PROGRESS

```
Traceback (most recent call last):
  File "segmenter.py", line 2, in <module>
    import mrcnn.config as config
  File "/lustre/fs0/home/neltenn/env/Mask_RCNN/GitHub/plantpod/api/machine_learning/mrcnn/config.py", line 10, in <module>
    import numpy as np
  File "/lustre/fs0/home/neltenn/env/lib64/python3.6/site-packages/numpy/__init__.py", line 140, in <module>
    from . import core
  File "/lustre/fs0/home/neltenn/env/lib64/python3.6/site-packages/numpy/core/__init__.py", line 48, in <module>
    raise ImportError(msg)
ImportError:

IMPORTANT: PLEASE READ THIS FOR ADVICE ON HOW TO SOLVE THIS ISSUE!

Importing the numpy C-extensions failed. This error can happen for
many reasons, often due to issues with your setup or how NumPy was
installed.

We have compiled some common reasons and troubleshooting tips at:

    https://numpy.org/devdocs/user/troubleshooting-importerror.html

Please note and check the following:

  * The Python version is: Python3.6 from "/lustre/fs0/home/neltenn/env/bin/python3"
  * The NumPy version is: "1.19.5"

and make sure that they are the versions you expect.
Please carefully study the documentation linked above for further help.

Original error was: PyCapsule_Import could not import module "datetime"

Segmentation fault (core dumped)
(env) [neltenn@evuser1 machine_learning]$
```

SOFTWARE SIDE - OVERVIEW



- Easily manage and compare data for scientists.
- Website, Database, and API

WEB REQUIREMENTS

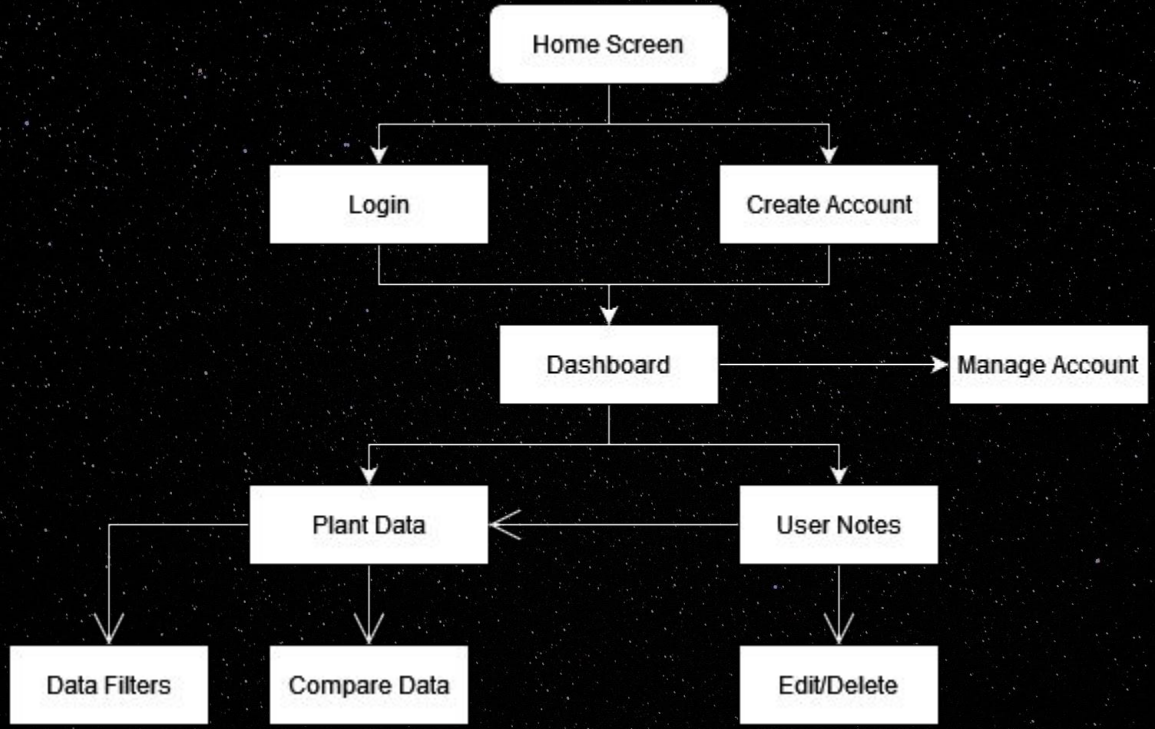
Users can log in to see:

- History
- Notes
- Photographs

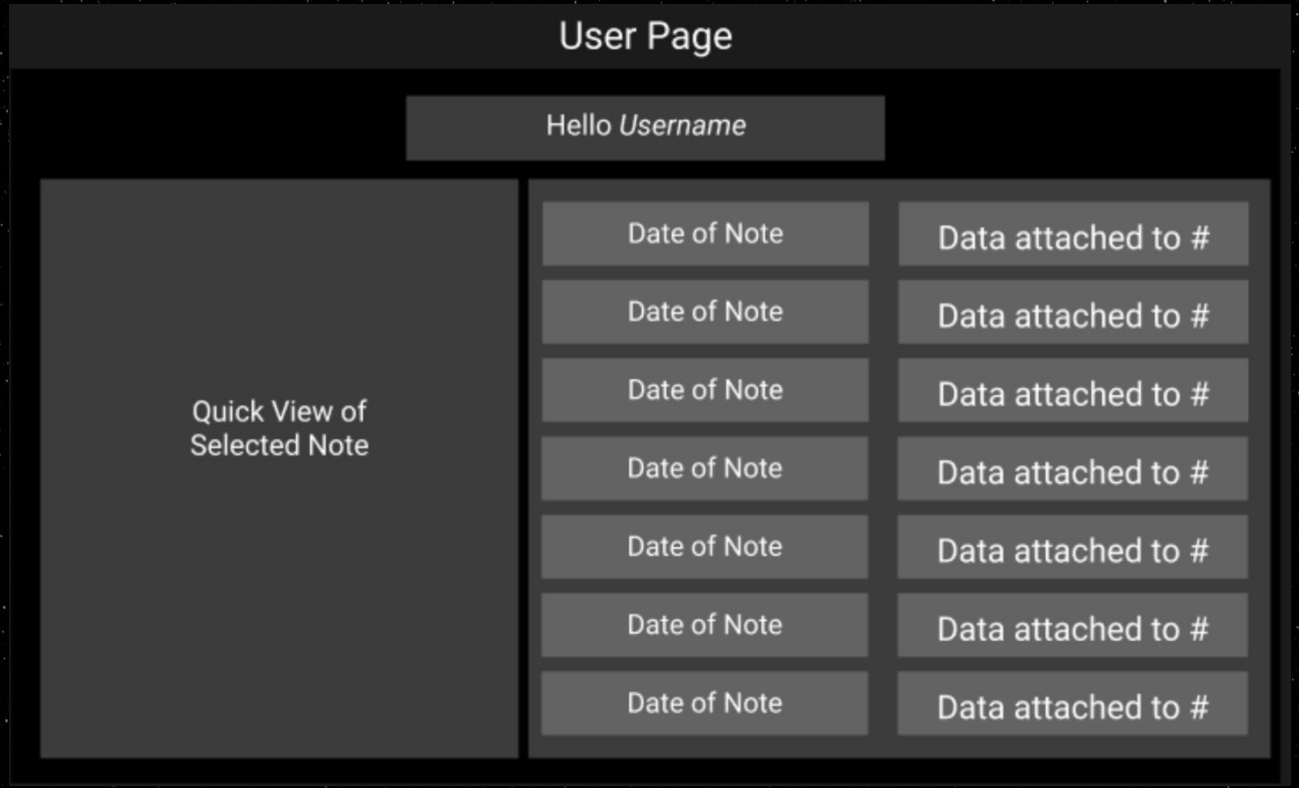
Notes:

- Compare
- Edit
- Delete

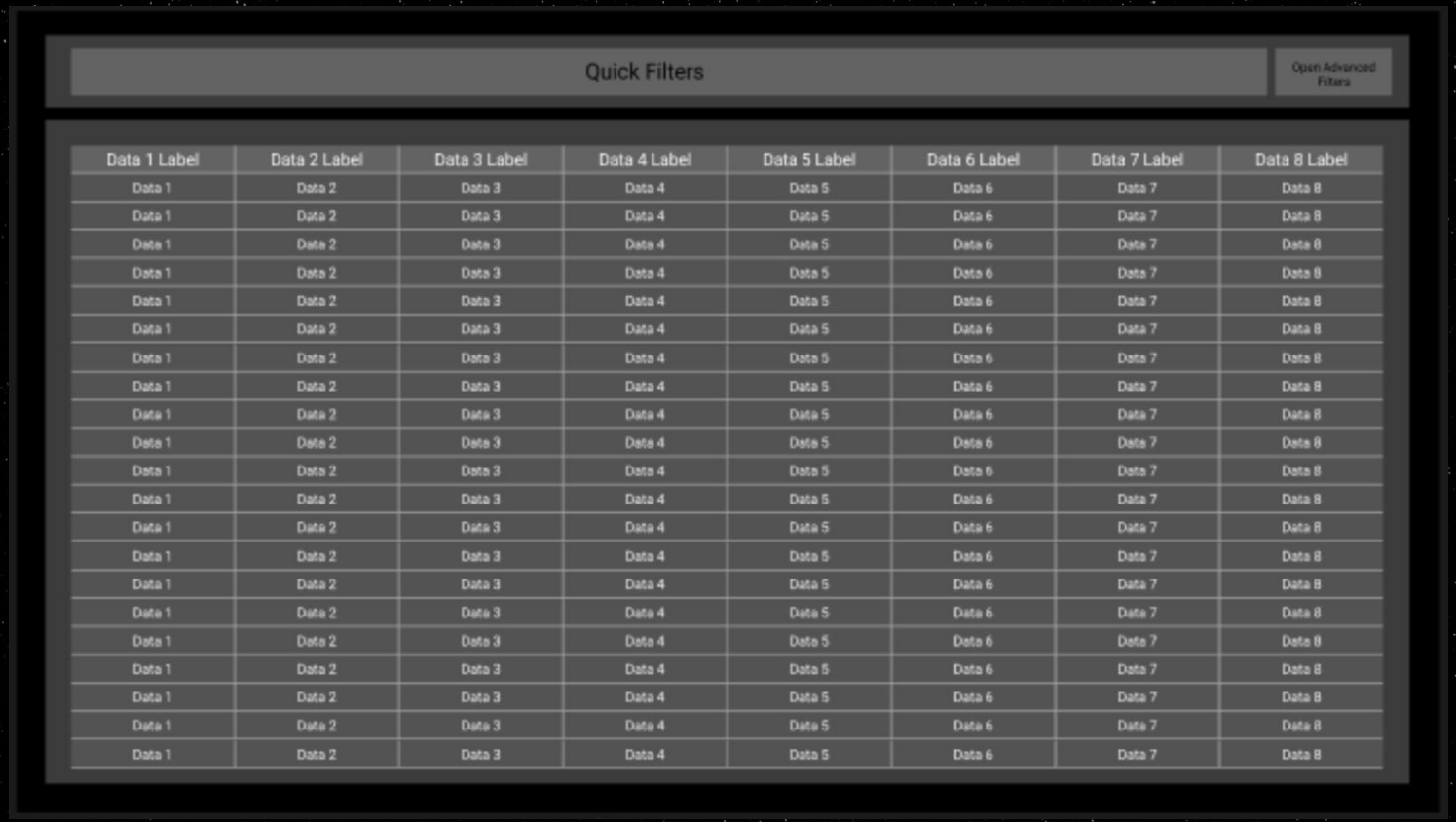
FRONTEND BLOCK DIAGRAM



PROTOTYPE USER PAGE



PROTOTYPE DATA PAGE



Data 1 Label	Data 2 Label	Data 3 Label	Data 4 Label	Data 5 Label	Data 6 Label	Data 7 Label	Data 8 Label
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Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Data 8
Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Data 8
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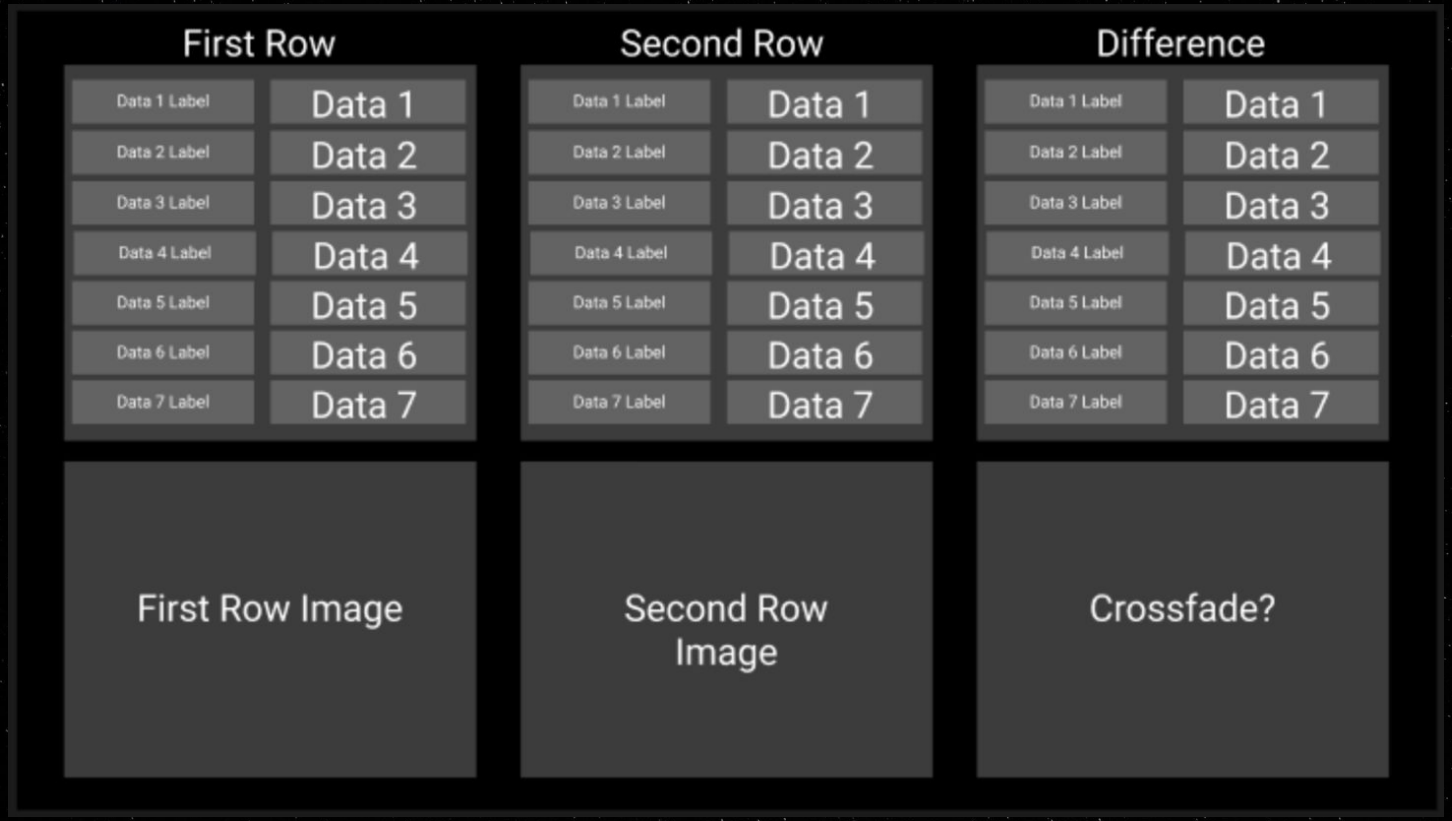
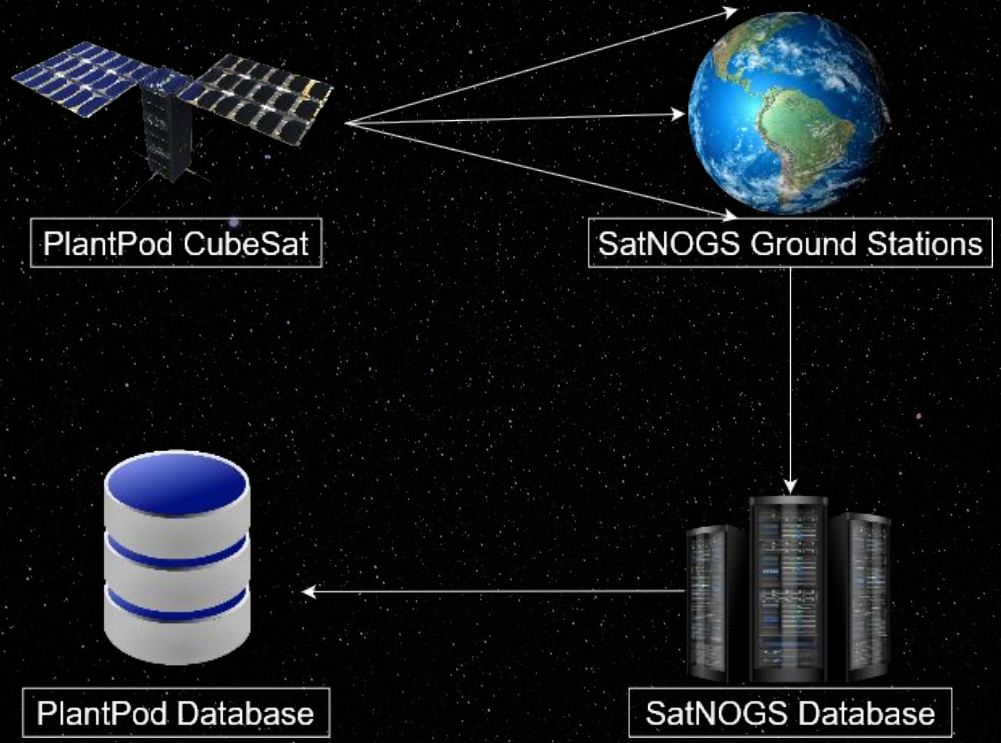
Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Data 8

PROTOTYPE DATA COMPARISON PAGE



DATA PATH


PlantPod CubeSat
SatNOGS Ground Stations
PlantPod Database
SatNOGS Database

TECHNOLOGIES USED

Websites & Apps	Web	Modified MERN Stack
GitHub	JavaScript	SQLite3
VSCode	CSS	ExpressJS
DigitalOcean	HTML	ReactJS
		NodeJS

WEB APPLICATION HOSTING

	Digital Ocean	GitHub
Price	Free $100 from Github Education	Free
Purpose	Virtual Machine Hosting	Collaboration

SOFTWARE SUCCESS AND CHALLENGES

Successes

- Useful libraries for React
- Hosting on DigitalOcean as a Droplet

Difficulties

- Transfer of data from physical sensors into database
- Swapping project focus from ISS module to satellite form

TEAM ORGANIZATION

	Discord weekly meetings
	Trello board
	Google Drive
	GitHub

BUDGET AND FINANCE THROUGH UCF

Item	Amount	Cost	Total
Arabidopsis Wild-Type Seed, Pack of 200	1	$16.10	$16.10
HiLetgo 5pcs Micro SD TF Card Adater Reader Mod	1	$6.99	$6.99
Adafruit SI1145 Digital UV Index/IR / Visible Light	1	$15.99	$15.99
LED Grow Lights for Indoor Plants, Full Spectrum P	1	$21.99	$21.99
Magenta GA-7 Plant Culture Box with Lid, Karter Sc	2	$6.99	$13.98
Bicool AS7341 Spectral Color Sensor 8X Visible Spe	2	$24.99	$49.98
BTF-LIGHTING WS2812B ECO RGB Alloy Wires 5050SMD I	1	$11.49	$11.49
2 Pack ESP32-CAM WiFi Bluetooth Camera Module Deve	1	$17.99	$17.99
Arabidopsis Germination Medium	1	$2.23	$2.23
Total			$151.81

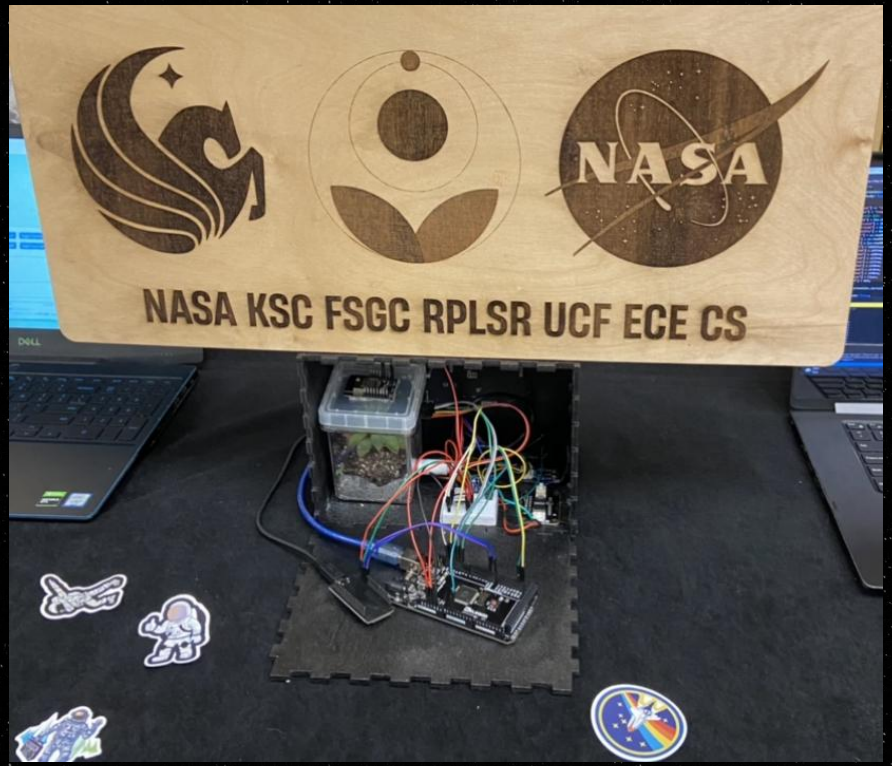
Excluding shipping and handling expenses.

BUDGET AND FINANCE THROUGH MATT AND NICK

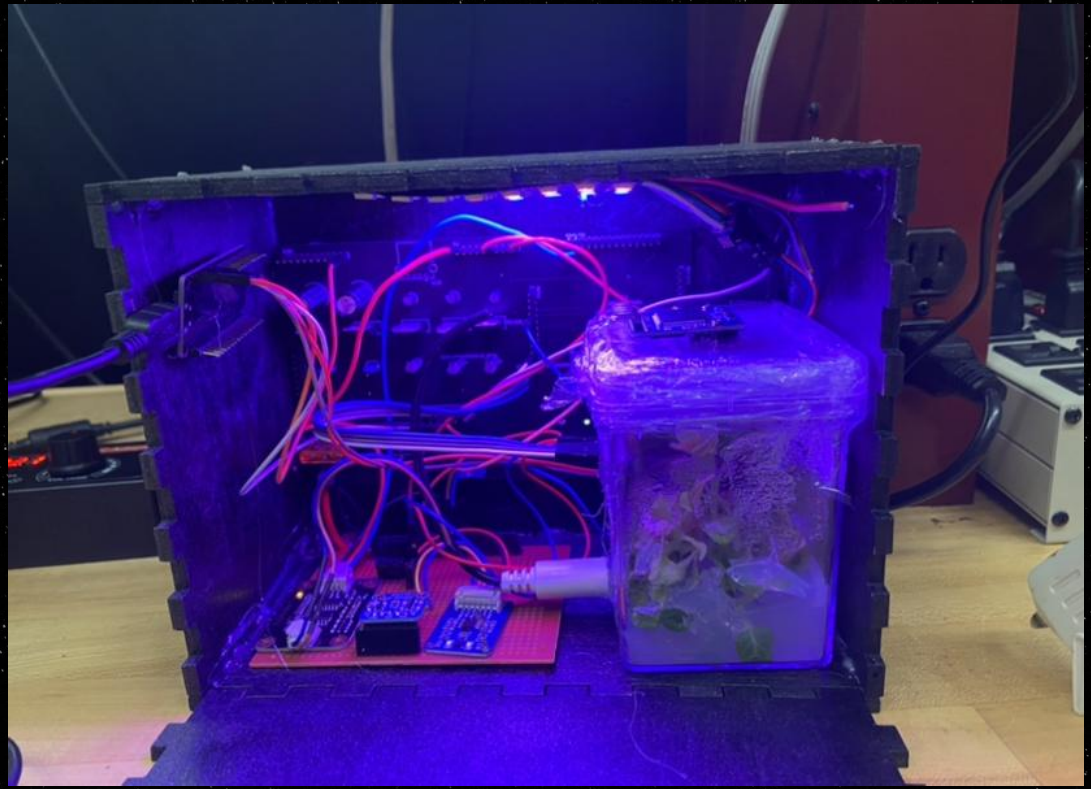
Item	Amount	Cost	Total
Printed Circuit Boards	1	$21.00	$21.00
ESP8266	1	$15.98	$15.98
Arducam	2	$25.99	$51.98
Adafruit BME Sensor	2	$20.96	$41.92
Total Dissolved Solids Sensor	1	$13.99	$13.99
Jumper cables	1	$6.79	$6.79
Solder 2 sizes	2	$8.99	$17.98
Power Supply	1	$15.95	$15.95
ATMega2560 Chips	1	$38.99	$38.99
Printed Circuit Board Components	1	$50.00	$50.00
Petri dishes	1	$12.99	$12.99
MS Medium	1	$23.36	$23.36
Micro SD Card	1	$13.99	$13.99
Total			$324.92

Excluding shipping and handling expenses.

STEM DAY AT UCF



WORKING PROTOTYPE



NEXT STEPS FOR FUTURE SENIOR DESIGN TEAMS

- Focus on edible leafy greens that help meet nutritional goals
- Grow test plants media in collaboration with Biology Department
- Incorporate a vent system for the payload for rate of diffusion
- Research Wisconsin Fast Plant (Brassica) instead of Arabidopsis
- Research connecting with the Deep Space Network for communication
- Conduct system vibration testing to simulate rocket launch
- Implement 3 layers of redundancy instead of radiation hardening
- Integrate and test solar panels to ensure independent power supply

THANK YOU FOR WATCHING

Final Demo
Senior Design 2

Group 30
04/20/22