Mike Taylor

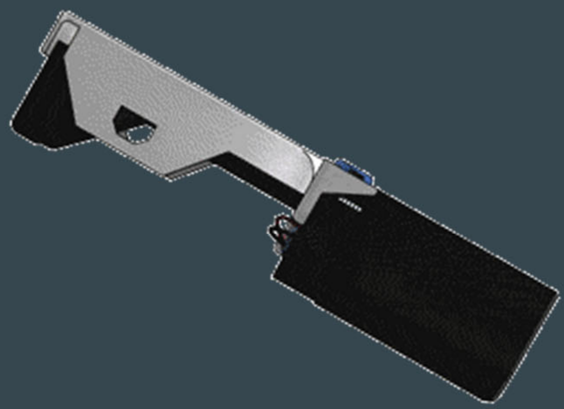
From Maryland

Landsat Outreach Scientist

Husband,
Father of two,
GIS major

STELLA
Team Lead

STELLA



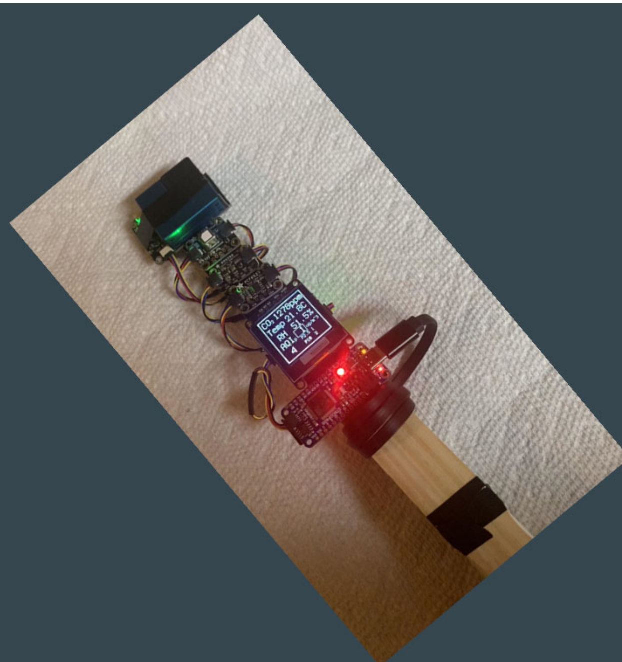
Science and Technology Education for Land / Life Assessment

What is STELLA?

- Low-Cost Modular Educational Tool
- Gain Hands-on Experience in Engineering
- Encourage Curiosity Through Authentic STEM Learning

Why STELLA?

- Demystify Remote Sensing Concepts
- Make NASA Satellite Data Understandable



STELLA Spectrometers: Exploring the Electromagnetic Spectrum

- Detects visible, near-infrared wavelengths, and surface temperature
- Incorporates 3D printing and soldering for advanced learning
- Imparts knowledge of electronics and mechanical engineering

STELLA-AQ: Demystifying Air Quality

- Measures CO2, particulates, temperature, humidity, and pressure
- Utilizes off-the-shelf components for easy assembly
- Fosters understanding of environmental monitoring systems

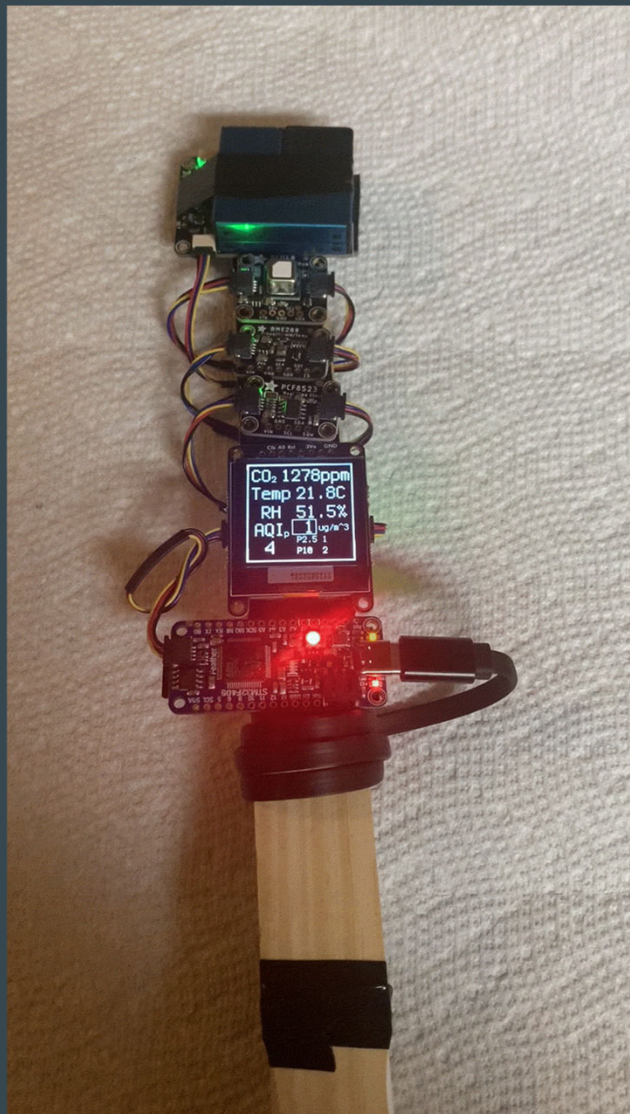
Helio-STELLA: Unveiling the Secrets of Sunlight

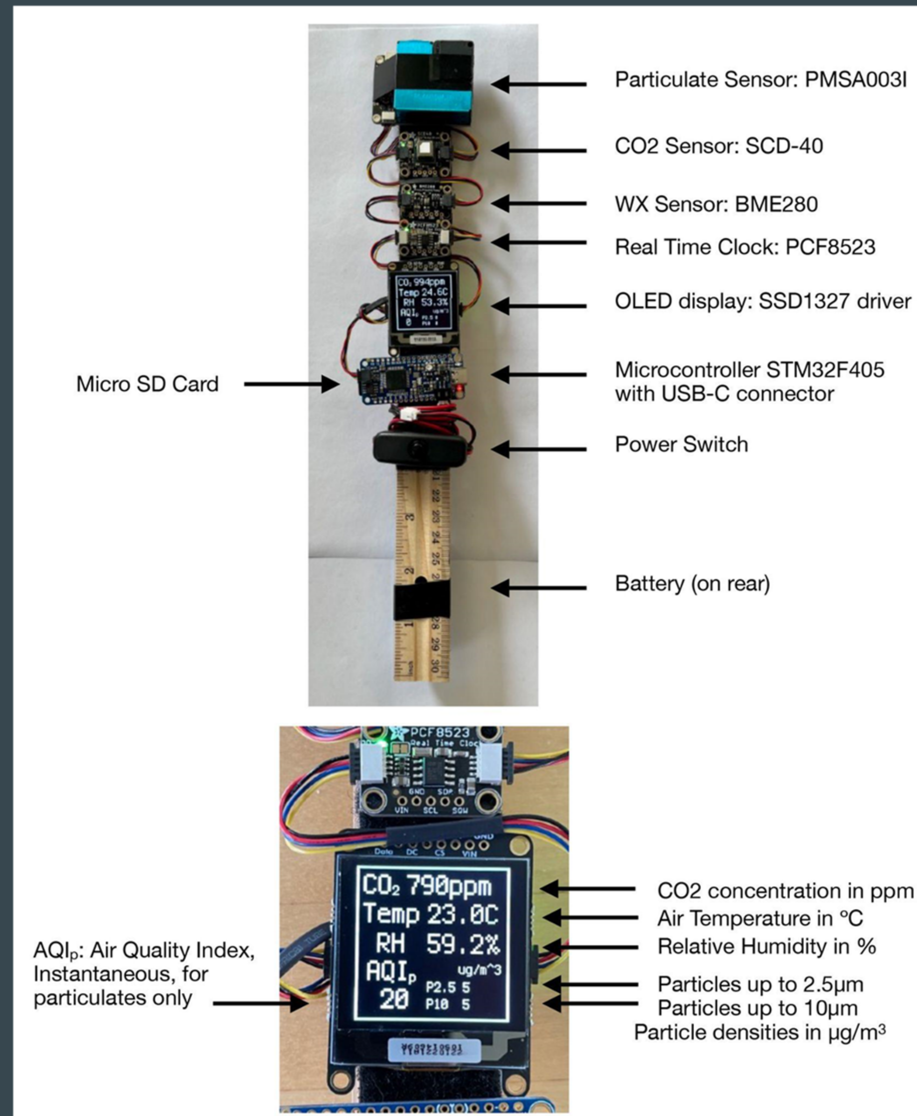
- Measures visible light spectrum in 8 channels and UVA as well
- Analyzes solar radiation intensity
- Introduces principles of optics and instrument design

STELLA-AQ


Paul Mirel


Dr. Nyssa Rayne


CO₂ 1278ppm
Temp 21.8C
RH 51.5%
AQIp


Particulate Sensor: PMSA003I
CO2 Sensor: SCD-40
WX Sensor: BME280
Real Time Clock: PCF8523
OLED display: SSD1327 driver
Micro SD Card
Microcontroller STM32F405 with USB-C connector
Power Switch
Battery (on rear)
PCF8523
CO₂ 790ppm
Temp 23.0C
RH 59.2%
AQIp ug/m^3
20 P2.5 5
P10 5
AQIp: Air Quality Index, Instantaneous, for particulates only
CO2 concentration in ppm
Air Temperature in °C
Relative Humidity in %
Particles up to 2.5µm
Particles up to 10µm
Particle densities in µg/m³

WHAT IS IN THE AIR?

Avi Jutla (6th Grade)

PURPOSE

The goal of my project is to understand the impact of Carbon Dioxide (CO_2) on human well-being in built environments (such as classrooms, homes, etc.). Within this context, the purpose is to:

1. Develop, fabricate and test a low-cost CO_2 sensor
2. Conduct basic experiments to observe how CO_2 affects air quality.

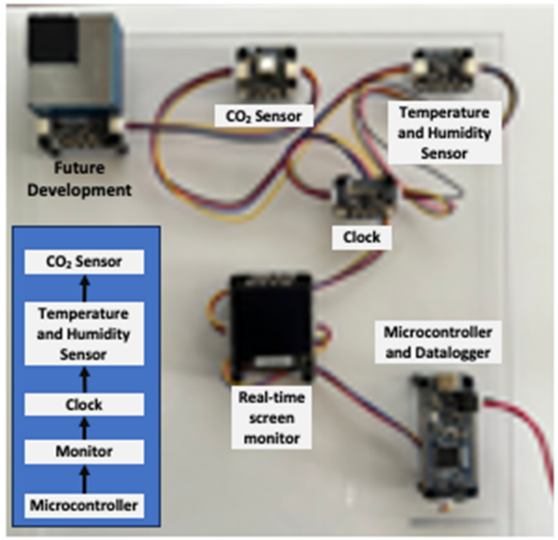
HYPOTHESIS

My working hypothesis for this year's school science project is that the amount of CO2 in a closed space (such as classrooms) is a function of congestion (measured by the number of students per square area) such that it will represent a lack of air circulation in the room.

ABSTRACT

Indoor Air Quality (IAQ) is vital to human well-being since we spend a considerable amount of time in the indoor built environment. In the United States, an individual, on average, spends 87% of their time indoors. According to the National Center for Education Statistics (NCES), about 49.4 million students are enrolled in the kindergarten to grade 12 (K-12) public school system. Lack of adequate indoor air quality can lead to increased school absences due to respiratory infections, allergic reactions from biological or chemical contaminants. From 2010 to 2016, 13% of students suffered from severe to moderate respiratory infections in the US. This represented a mean of school absenteeism of 4.5 days per year per student. Two observations form the motivation to develop a low-cost sensor for monitoring CO2 in classrooms: (i) every year, a sizable population of students in my class get respiratory infections and (ii) during the transition from cold to hot (or vice versa) indoor air, indicative of a lack of airflow in classrooms. Therefore, if I can detect changes in CO2 concentrations, then I will be able to provide an assessment of safe thresholds (current level are at 1000ppm for indoor built environments according to the American Society of Heating, Refrigeration, and Air Conditioning Engineers) at which air may be changed in the room through mechanical ventilation. After designing, fabricating, testing, and programming the sensor in CircuitPython, my project will collect data on instantaneous and continuous measurements of CO2 concentration. Two experiments will be conducted through simulations: (i) **estimate levels of CO_2 through forced exhaling on the sensor and observe changes in the CO_2 readings** and (ii) **measure changes in the amount of CO_2 through congestion in a prescribed space.**

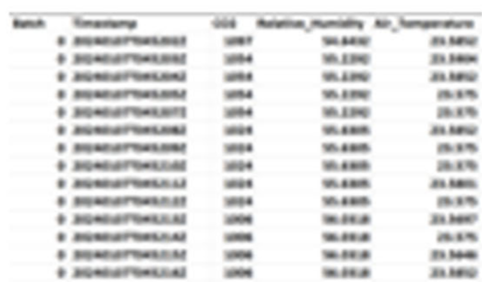
MATERIALS AND PROCEDURE



Sensor Schematics and Programming

Operation

DATA COLLECTED



Batch:
Unique ID for experiment

Timestamp:
Date and time of data collected

CO2:
Carbon Dioxide Concentration

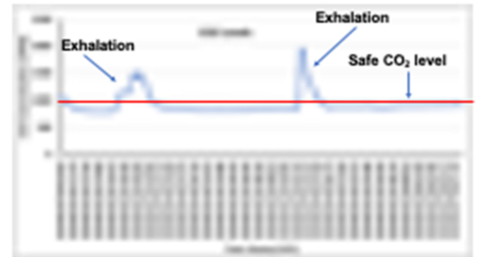
Relative Humidity:
Amount of moisture in the air in percentage.

Air Temperature:
Air temperature in degrees Celsius.

RESULTS

SIMULATION EXPERIMENT 1

Estimate levels of CO_2 through forced exhaling on the sensor and observe changes in the CO_2 readings



SIMULATION EXPERIMENT 2

Measure changes in the amount of CO_2 through congestion in a prescribed space.

Given space: 3 ft x 4 ft = 12 sqft of area; Number of people: 3

CO_2 levels without any person in the space: 700ppm

CO_2 levels with 3 persons in 12 sqft of area: 840ppm

Percent change = 20% per 12 sqft (or 6% per person per 12sqft)

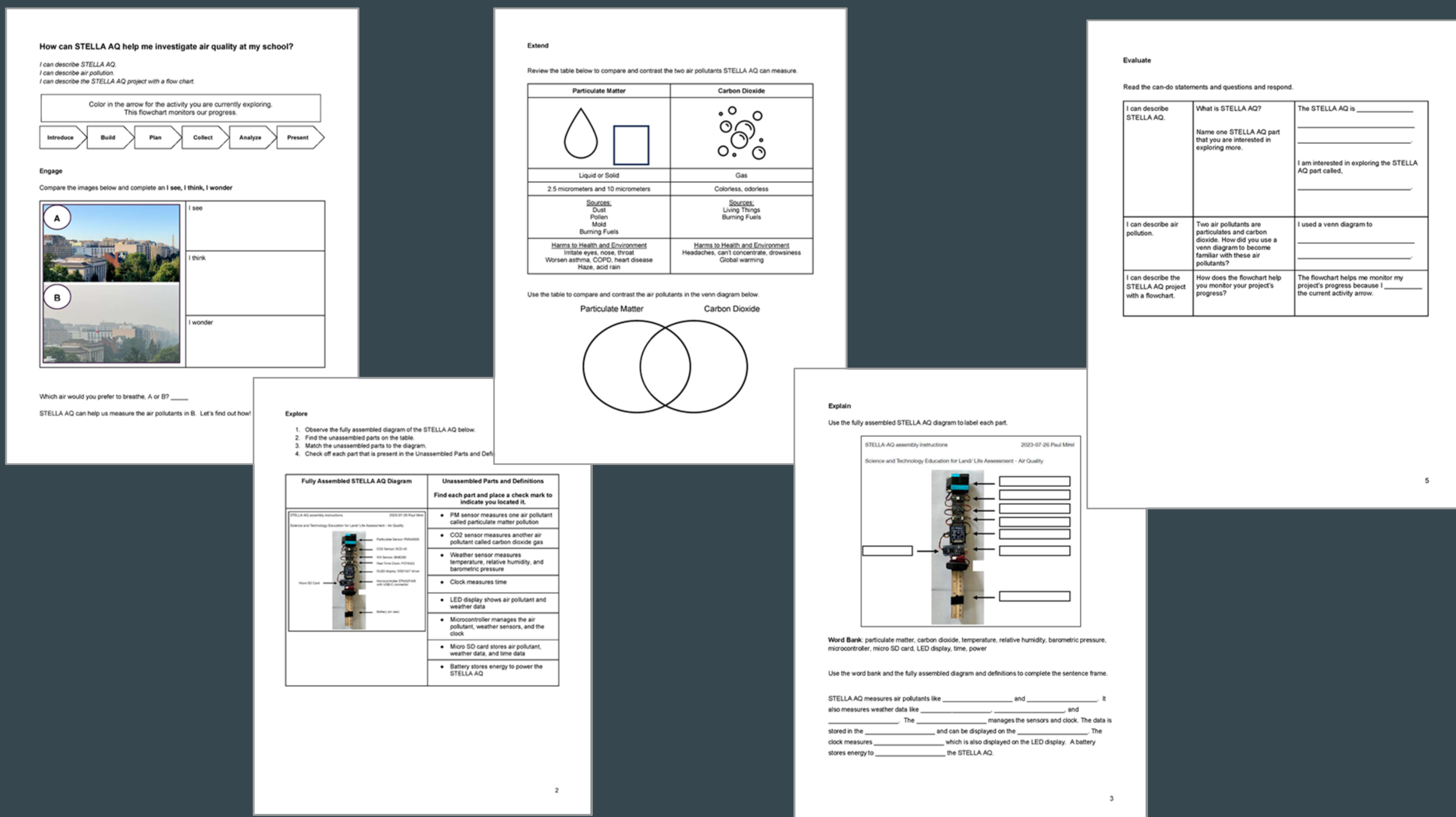
CONCLUSIONS

1. A low-cost sensor was developed, fabricated, and tested. The cost of the sensor is ~$75.00. It has the capability to measure accurate levels of CO_2 in built environments.
2. Significant increases in the level of CO_2 were observed in the congested simulation settings where CO_2 increased by 6% per person per 12sqft. This provides impetus to collect real-time data in classrooms.
3. Operation of the CO_2 sensor was satisfactory through exhaling experiments.

REFERENCES

- Juliana P. Sá, Maria Conceição M. A., Fernando G. M., Sofia I. V. S., (2022) Application of the low-cost sensing technology for indoor air quality monitoring: A review, *Environmental Technology & Innovation* **28**, 102551, [illegible]
- Raymenants, J., Geenen, C., Budts, L. et al. (2023) Indoor air surveillance and factors associated with respiratory pathogen detection in community settings in Belgium. *Nat Commun* **14**, 1332. [illegible]
- Rembor, K., (2021) CO₂ Sensor Programming and Operation, [illegible] (accessed on [illegible]).
- Rembor, K., (2017) Guide to learning CircuitPython, [illegible] (accessed and downloaded on [illegible]). This was followed up with exploring the full package available as a free resource at [illegible]
- Amgen Foundation (2023) How to interpret histograms, [illegible] (accessed on [illegible])

Elizabeth Spike - Lessons



How can STELLA AQ help me investigate air quality at my school?

I can describe STELLA AQ.
I can describe air pollution.
I can describe the STELLA AQ project with a flow chart.

Color in the arrow for the activity you are currently exploring. This flowchart monitors our progress.

Introduce → Build → Plan → Collect → Analyze → Present

Engage

Compare the images below and complete an **I see, I think, I wonder**

A
B

I see
I think
I wonder

Which air would you prefer to breathe, A or B? _____

STELLA AQ can help us measure the air pollutants in B. Let's find out how!

Explore

1. Observe the fully assembled diagram of the STELLA AQ below.
2. Find the unassembled parts on the table.
3. Match the unassembled parts to the diagram.
4. Check off each part that is present in the Unassembled Parts and Defi...

Fully Assembled STELLA AQ Diagram	Unassembled Parts and Definitions Find each part and place a check mark to indicate you located it.
	• PM sensor measures one air pollutant called particulate matter pollution
	• CO2 sensor measures another air pollutant called carbon dioxide gas
	• Weather sensor measures temperature, relative humidity, and barometric pressure
	• Clock measures time
	• LED display shows air pollutant and weather data
	• Microcontroller manages the air pollutant, weather sensors, and the clock
	• Micro SD card stores air pollutant, weather data, and time data
	• Battery stores energy to power the STELLA AQ

2

Extend

Review the table below to compare and contrast the two air pollutants STELLA AQ can measure.

Particulate Matter	Carbon Dioxide
Liquid or Solid	Gas
2.5 micrometers and 10 micrometers	Colorless, odorless
Sources: Dust Pollen Mold Burning Fuels	Sources: Living Things Burning Fuels
Harms to Health and Environment Irritate eyes, nose, throat Worsen asthma, COPD, heart disease Haze, acid rain	Harms to Health and Environment Headaches, can't concentrate, drowsiness Global warming

Use the table to compare and contrast the air pollutants in the venn diagram below.

Particulate Matter
Carbon Dioxide

Explain

Use the fully assembled STELLA AQ diagram to label each part.

STELLA-AQ assembly instructions 2023-07-26 Paul Mirel
Science and Technology Education for Land/ Life Assessment - Air Quality

Word Bank: particulate matter, carbon dioxide, temperature, relative humidity, barometric pressure, microcontroller, micro SD card, LED display, time, power

Use the word bank and the fully assembled diagram and definitions to complete the sentence frame.

STELLA AQ measures air pollutants like ______________ and ______________. It also measures weather data like ______________, ______________, and ______________. The ______________ manages the sensors and clock. The data is stored in the ______________ and can be displayed on the ______________. The clock measures ______________ which is also displayed on the LED display. A battery stores energy to ______________ the STELLA AQ.

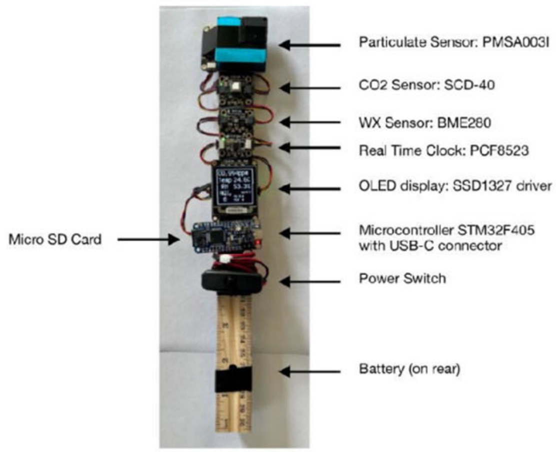
3

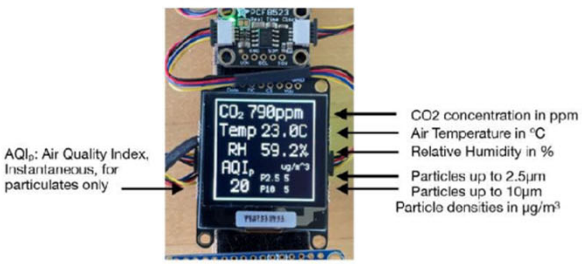
Evaluate

Read the can-do statements and questions and respond.

I can describe STELLA AQ.	What is STELLA AQ? Name one STELLA AQ part that you are interested in exploring more.	The STELLA AQ is ____________ ____________. I am interested in exploring the STELLA AQ part called, ____________.
I can describe air pollution.	Two air pollutants are particulates and carbon dioxide. How did you use a venn diagram to become familiar with these air pollutants?	I used a venn diagram to ____________ ____________.
I can describe the STELLA AQ project with a flowchart.	How does the flowchart help you monitor your project's progress?	The flowchart helps me monitor my project's progress because I ________ the current activity arrow.

5





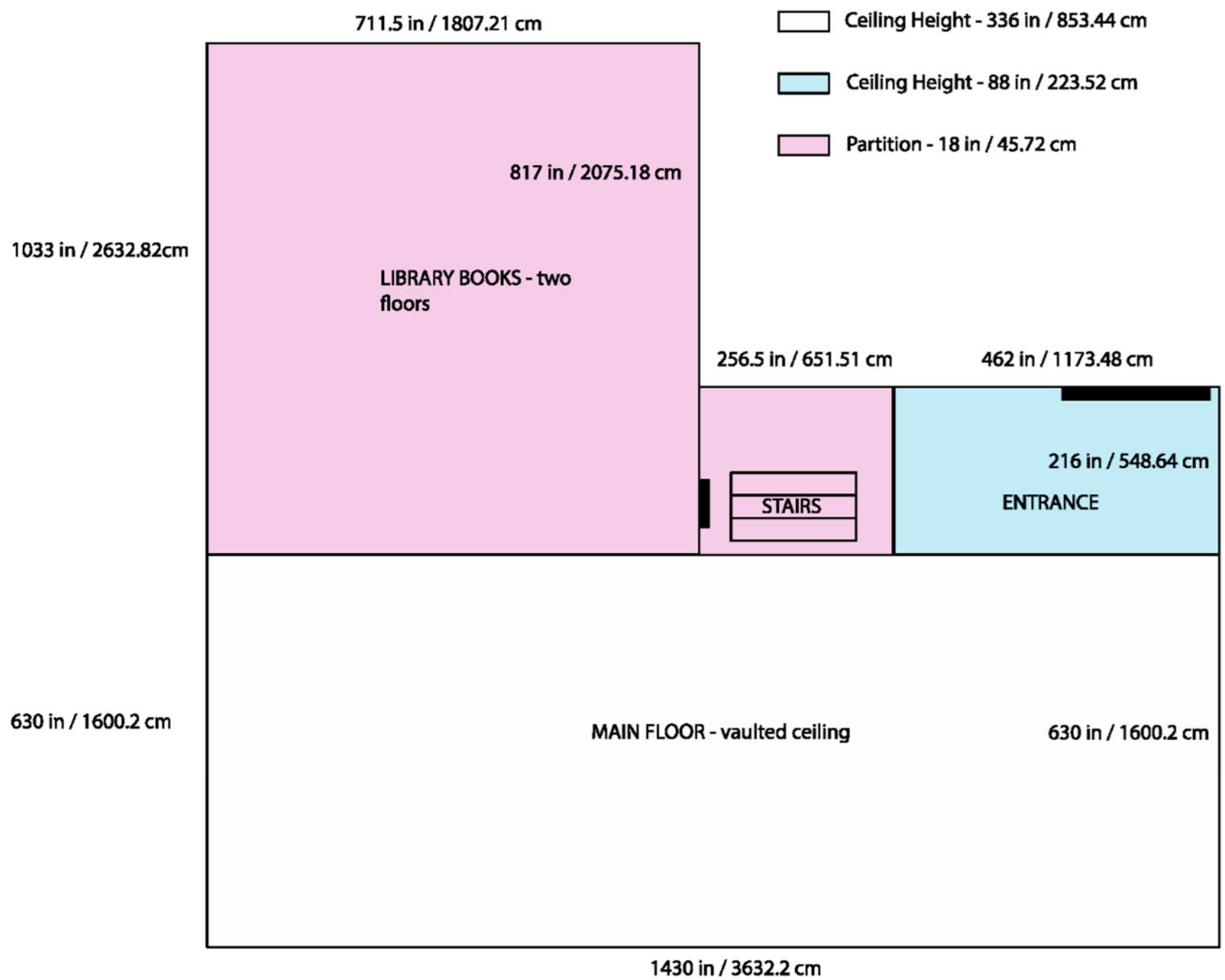
Experiment Setup:

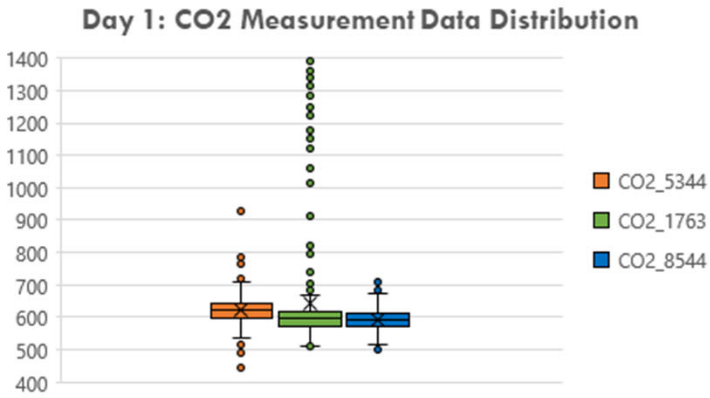
* 3 STELLA-AQs

* 11/15/2023
8:00 AM – 5:00 PM
(not turned off for lunch break)

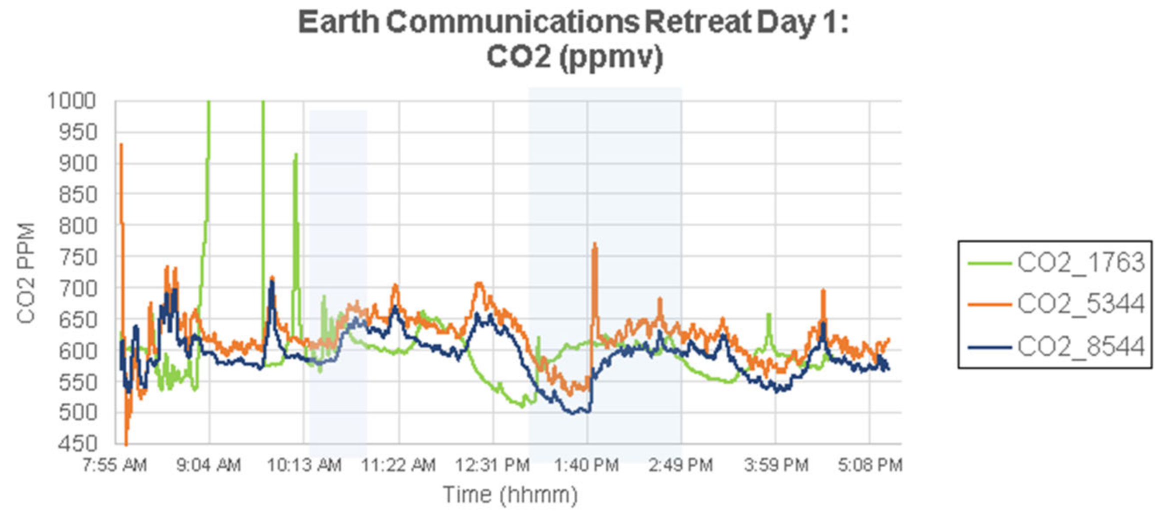
* All instruments where within about 3 inches of another standing up (vertical)

* Placed in center of table near front of room

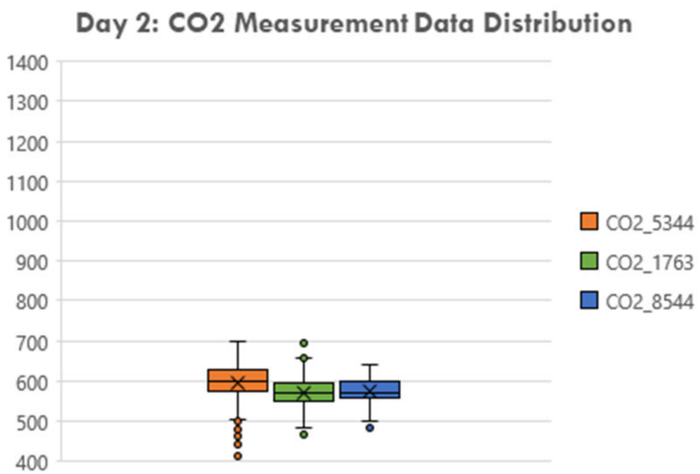




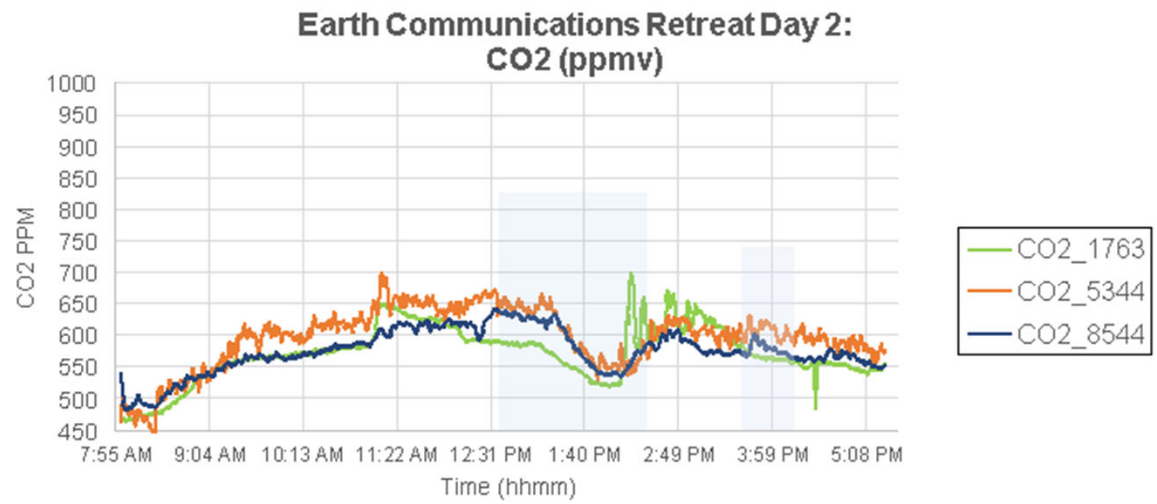
Day 1: CO2 Measurement Data Distribution
1400
1300
1200
1100
1000
900
800
700
600
500
400
CO2_5344
CO2_1763
CO2_8544



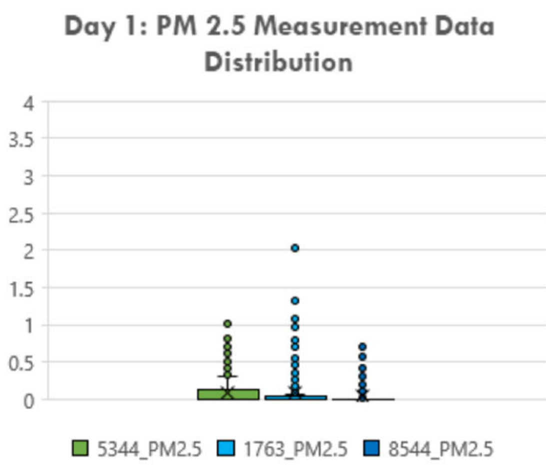
Earth Communications Retreat Day 1: CO2 (ppmv)
CO2 PPM
Time (hhmm)
7:55 AM
9:04 AM
10:13 AM
11:22 AM
12:31 PM
1:40 PM
2:49 PM
3:59 PM
5:08 PM
CO2_1763
CO2_5344
CO2_8544

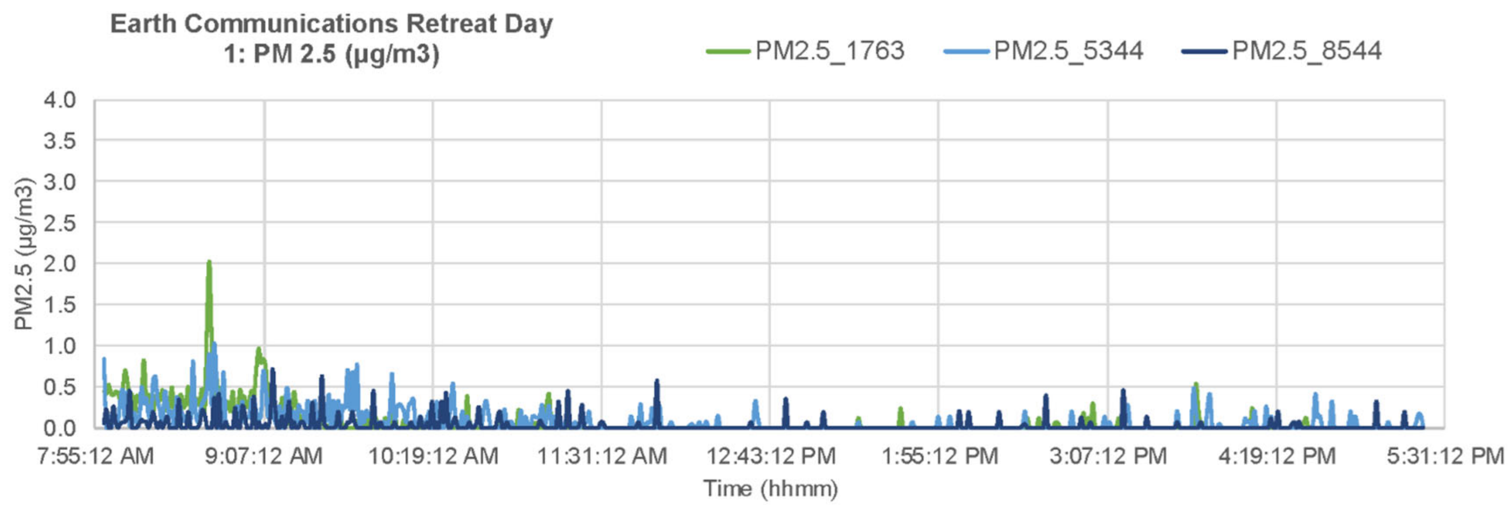


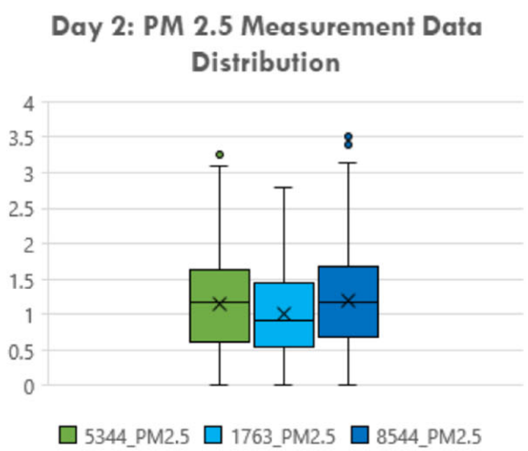
Day 2: CO2 Measurement Data Distribution
CO2_5344
CO2_1763
CO2_8544

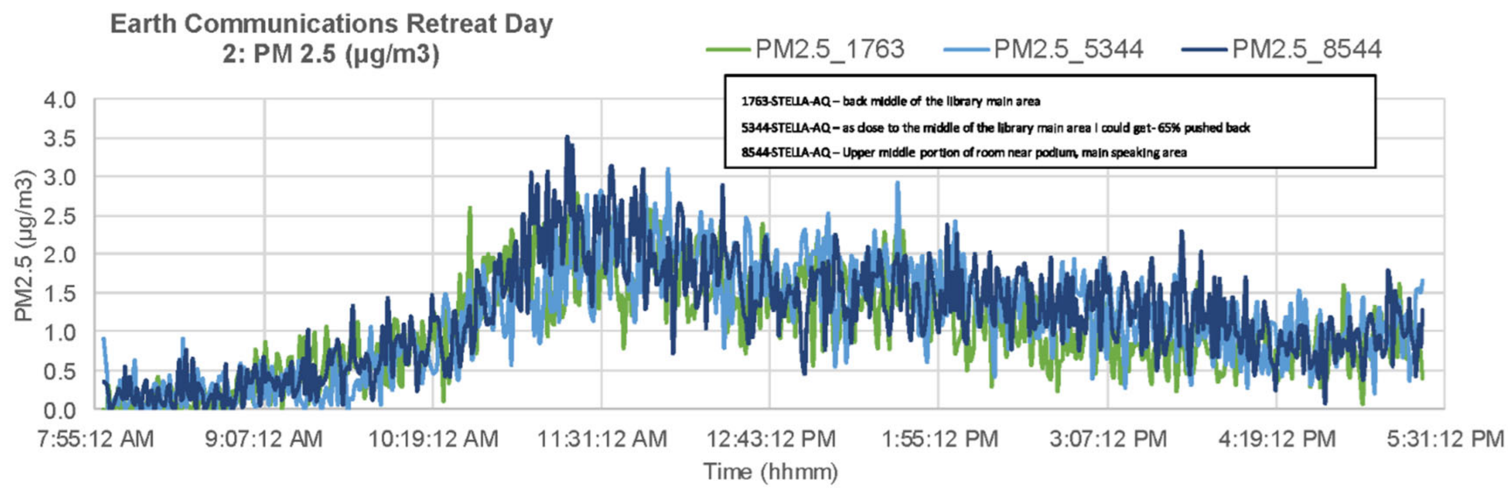


Earth Communications Retreat Day 2: CO2 (ppmv)
CO2 PPM
Time (hhmm)
7:55 AM
9:04 AM
10:13 AM
11:22 AM
12:31 PM
1:40 PM
2:49 PM
3:59 PM
5:08 PM
CO2_1763
CO2_5344
CO2_8544

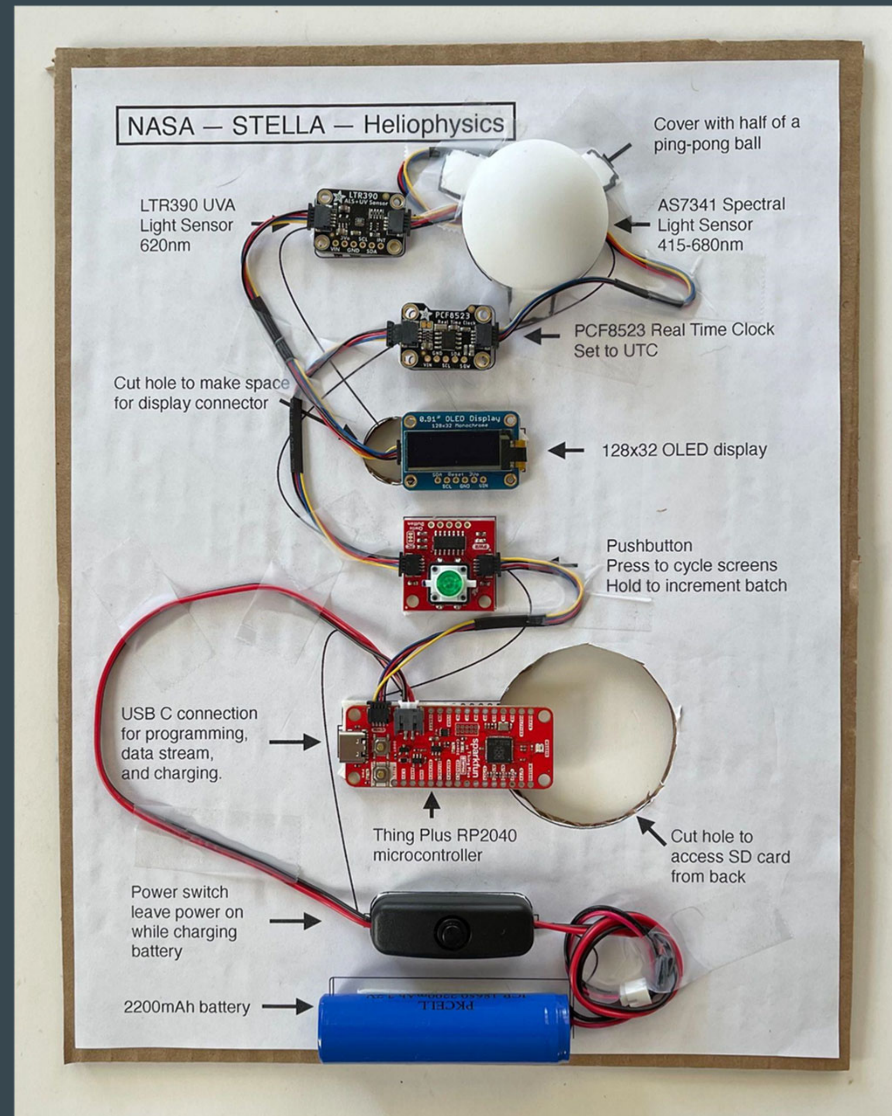

Day 1: PM 2.5 Measurement Data Distribution
4
3.5
3
2.5
2
1.5
1
0.5
0
5344_PM2.5
1763_PM2.5
8544_PM2.5


Earth Communications Retreat Day 1: PM 2.5 (µg/m3)
PM2.5_1763
PM2.5_5344
PM2.5_8544
PM2.5 (µg/m3)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7:55:12 AM
9:07:12 AM
10:19:12 AM
11:31:12 AM
12:43:12 PM
1:55:12 PM
3:07:12 PM
4:19:12 PM
5:31:12 PM
Time (hhmm)

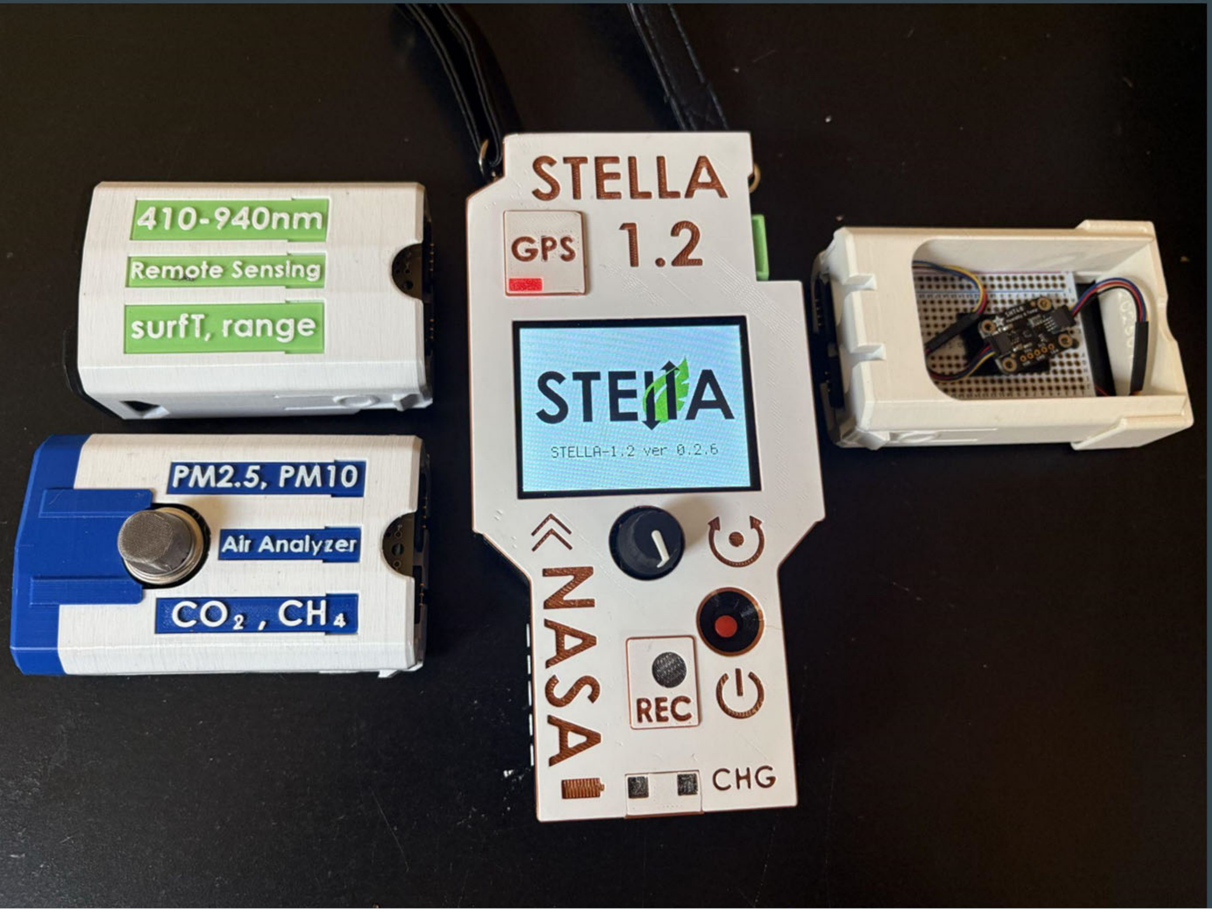

Day 2: PM 2.5 Measurement Data Distribution
4
3.5
3
2.5
2
1.5
1
0.5
0
5344_PM2.5
1763_PM2.5
8544_PM2.5


Earth Communications Retreat Day 2: PM 2.5 (µg/m3)
PM2.5_1763
PM2.5_5344
PM2.5_8544
1763-STELLA-AQ – back middle of the library main area
5344-STELLA-AQ – as close to the middle of the library main area I could get- 65% pushed back
8544-STELLA-AQ – Upper middle portion of room near podium, main speaking area
PM2.5 (µg/m3)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7:55:12 AM
9:07:12 AM
10:19:12 AM
11:31:12 AM
12:43:12 PM
1:55:12 PM
3:07:12 PM
4:19:12 PM
5:31:12 PM
Time (hhmm)

Helio-STELLA

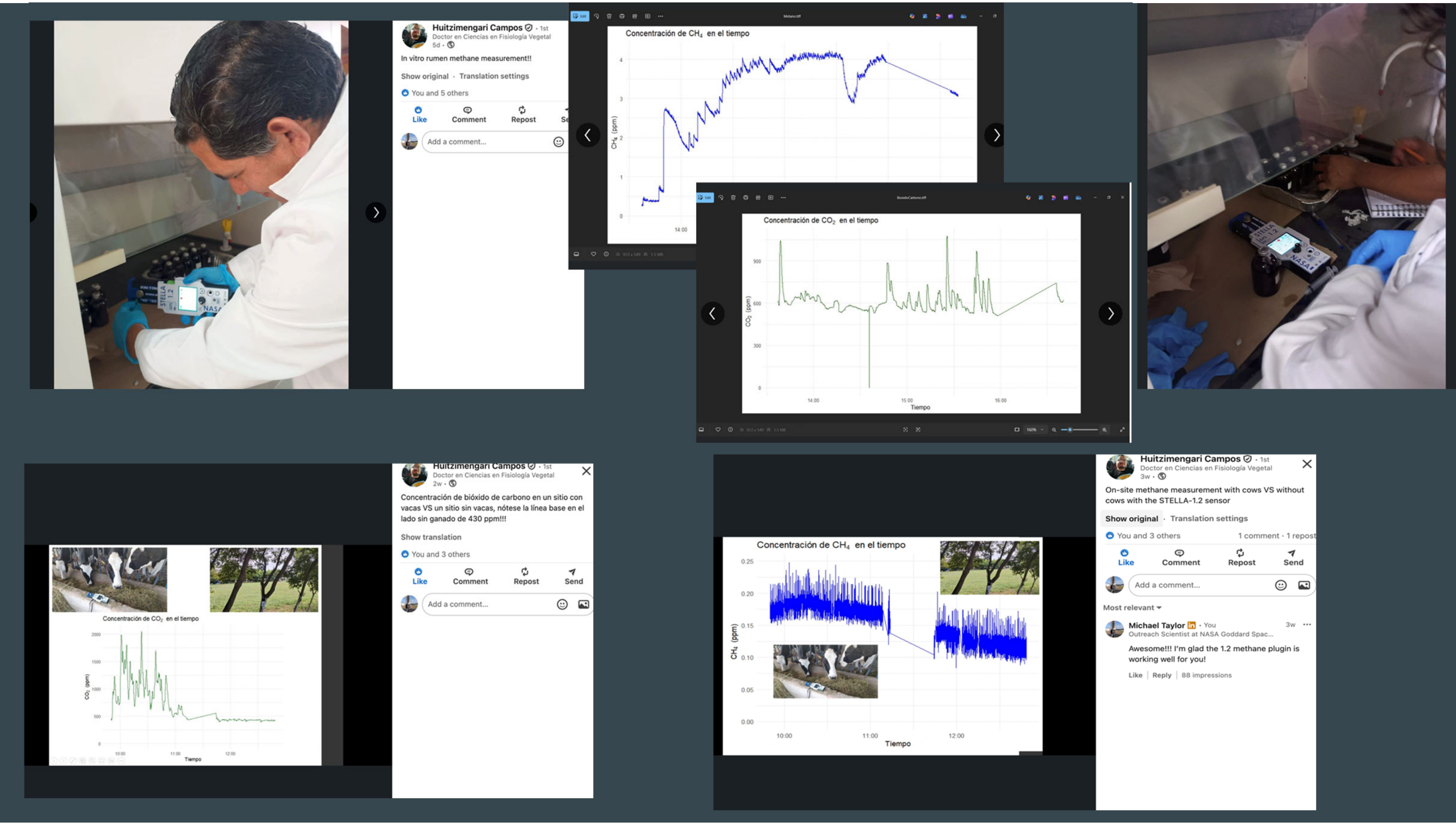


STELLA-1.2


410-940nm
Remote Sensing
surfT, range
PM2.5, PM10
Air Analyzer
CO2 , CH4
STELLA
1.2
GPS
STELLA
STELLA-1.2 ver 0.2.6
NASA
REC
CHG


CO2 , CH4
Air Analyzer
PM2.5, PM10


STELLA
GPS
1.2
NASA
REC
CHG



Huitzimengari Campos · 1st
Doctor en Ciencias en Fisiología Vegetal
5d
In vitro rumen methane measurement!!
Show original · Translation settings
You and 5 others
Like
Comment
Repost
Add a comment...
STELLA 1.2
NASA
Concentración de CH_4 en el tiempo
CH_4 (ppm)
14:00
Concentración de CO_2 en el tiempo
CO_2 (ppm)
14:00
15:00
16:00
Tiempo
Huitzimengari Campos · 1st
Doctor en Ciencias en Fisiología Vegetal
2w
Concentración de bióxido de carbono en un sitio con vacas VS un sitio sin vacas, nótese la línea base en el lado sin ganado de 430 ppm!!!
Show translation
You and 3 others
Like
Comment
Repost
Send
Add a comment...
Concentración de CO_2 en el tiempo
CO_2 (ppm)
10:00
11:00
12:00
Tiempo
Concentración de CH_4 en el tiempo
CH_4 (ppm)
0.25
0.20
0.15
0.10
0.05
0.00
10:00
11:00
12:00
Tiempo
Huitzimengari Campos · 1st
Doctor en Ciencias en Fisiología Vegetal
3w
On-site methane measurement with cows VS without cows with the STELLA-1.2 sensor
Show original · Translation settings
You and 3 others
1 comment · 1 repost
Like
Comment
Repost
Send
Add a comment...
Most relevant
Michael Taylor · You
Outreach Scientist at NASA Goddard Spac...
3w
Awesome!!! I'm glad the 1.2 methane plugin is working well for you!
Like | Reply | 88 impressions

STELLA-AM Atmosphere Monitor

Science and Technology Education for Land/ Life Assessment.

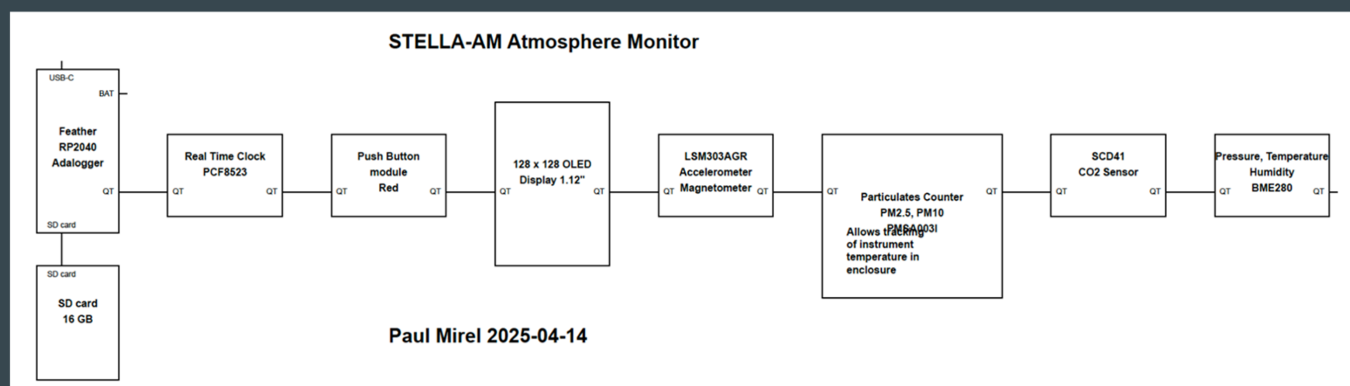
Monitors and records, with datestamp and timestamp:
Carbon dioxide
Particulates, PM2.5 and PM10
Barometric pressure
Air Temperature
Relative Humidity
Acceleration in 3 axes.
Magnetic field in 3 axes

Exceptional item. Made of electronic circuit boards, and PLA plastic (made from corn starch). There is no battery in this item. It runs off USB-C power, which will need to be provided externally.

Weight is 4 ounces.

Size is 4.9 x 2.3 x 0.7 inches.

Flown item will be presented to the NASA Astronaut Corps, to use in presentations at schools.

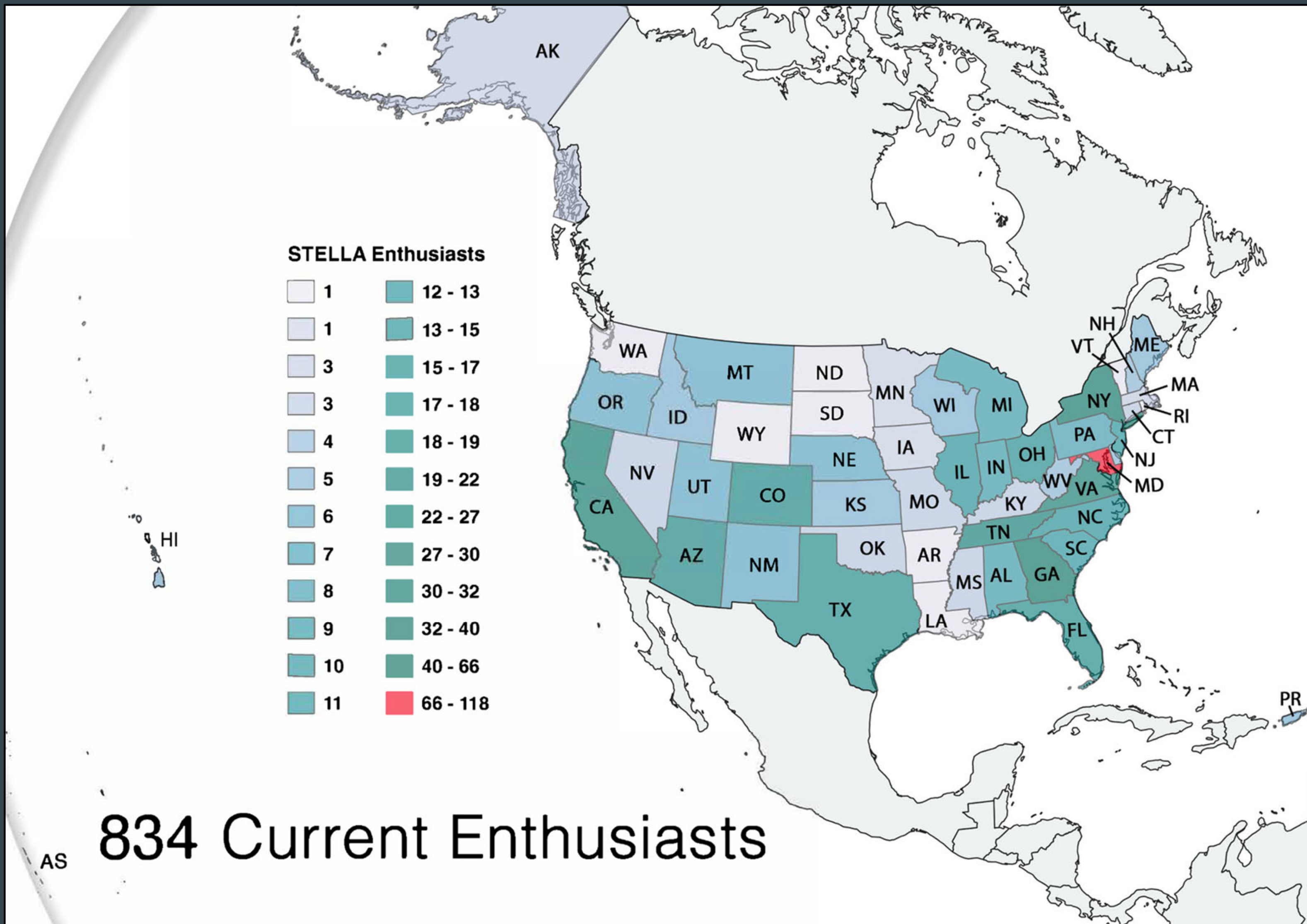


Manufacturing and Engineering Aspects of the STELLA Project

The STELLA (Science and Technology Education for Land/Life Assessment) project touches on multiple engineering disciplines:

1. **Additive Manufacturing** - Using 3D printed parts for instrument construction
2. **Design for Manufacturing** - Creating components that can be produced effectively
3. **Embedded Systems Software Engineering** - Creating software for microcontroller-driven devices
4. **Software Engineering** - Including cooperative multitasking techniques
5. **Electrical Engineering** - Connecting components, building functioning electronic systems, and soldering
6. **Electronics Packaging Engineering** - Designing enclosures and cable routing
7. **Mechanical Engineering** - Including snap joints and material properties
8. **Optical Engineering** - Working with wavelengths, field of view, and concepts like irradiance
9. **Indoor Air Quality Engineering** - Monitoring CO2 and particulate levels
10. **HVAC Engineering** - Related to environmental air quality
11. **Chemical Process Control Engineering** - Through liquid analysis instruments
12. **Civil and Hydrological Engineering** - Water quality analysis
13. **Sensor Engineering** - Working with various types of sensors
14. **Device Physics** - Understanding how different sensors function

The STELLA project serves as a platform that introduces these many engineering disciplines through hands-on experience with the instruments.



834 Current Enthusiasts
STELLA Enthusiasts
1
1
3
3
4
5
6
7
8
9
10
11
12 - 13
13 - 15
15 - 17
17 - 18
18 - 19
19 - 22
22 - 27
27 - 30
30 - 32
32 - 40
40 - 66
66 - 118
AK
HI
AS
PR
WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
PA
VA
NC
SC
NY
VT
NH
ME
MA
RI
CT
NJ
MD

STELLA SUITE

Model #	NASA Tie Ins	Applications/Use	Measurements	Build Time	Cost
Lookers					
STELLA-1.1	Landsat, PACE	plant health, UHI (urban heat island)	12 bands from visible blue to red and invisible near-infrared (450-860nm), broad band thermal	5 hours	~$200
STELLA-Q2	Landsat, PACE	plant health	18 bands from visible violet to red and invisible near-infrared (410-940nm)	15 - 30 min	~$150
Helio-STELLA	Aeronet	incoming solar radiation	10 bands from visible violet to red (415-680nm)	15 - 30 min	~$100
Sniffer					
STELLA-AQ	Aeronet, PACE	smoke, dust aerosols	particulates 2.5 and 10, CO_2, relative humidity, barometric pressure	15 - 30 min	~$150
Sniffer/Looker					
STELLA-1.2		base module for swappable sensor packages		5 hours	~$180
Remote Sensing plugin for 1.2	Landsat, PACE	plant health, UHI (urban heat island)	18 bands from visible violet to red and invisible near-infrared (410-940nm), broad band thermal	30 - 45 min	~$170
Air Analyzer plugin for 1.2	PACE	smoke, dust aerosols	methane CH_4, particulates 2.5 and 10, carbon dioxide CO_2, relative humidity, barometric pressure	30 - 45 min	~$130

Links

STELLA

STELLA
science.gsfc.nasa.gov/stella

AERONET
aeronet.gsfc.nasa.gov/

GMAO
https://gmao.gsfc.nasa.gov/