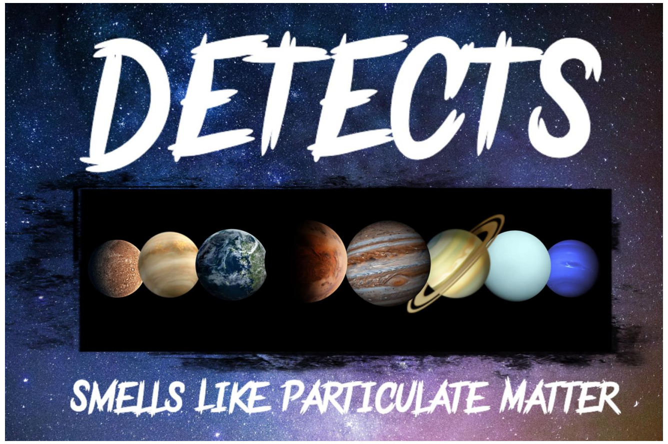
Team Progress Report 5

Smells Like Particulate Matter
Palmetto Scholars Academy
Team 1



Team Lead
Michael
Blunt
11th Grade

Experiment Lead
Max
Freedman
11th Grade

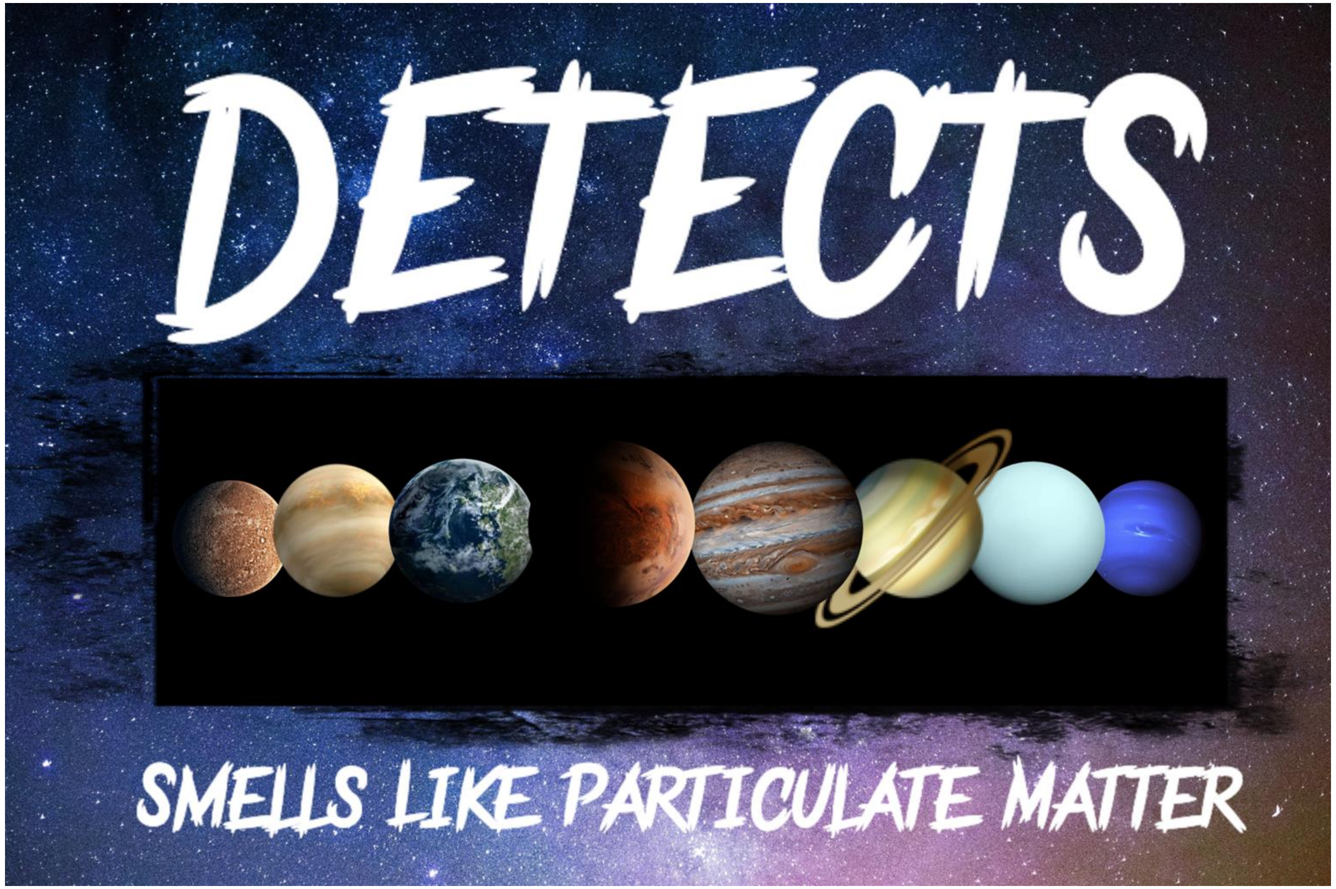
Test Lead
Emann
Rivero
12th Grade

Experiment Group
Benjamin
Deaton
11th Grade

Chief Engineer
Samantha
Quartuccio
12th Grade

Test Group/Outreach
Morgan
Peterson
11th Grade

Smells Like Particulate Matter



"[Our] goal is simple. It is a complete understanding of the universe, why is it as it is and why it exists at all" – Stephen Hawking

ACES RED 2B

- Studying quantum entanglement for space satellite communications.
  - Sponsored by U.S. Space and Missile Defense Command (SMDC)
- Secondarily investigating the use of low-cost commercial-off-the-shelf (COTS) hardware
  - To replace currently used expensive equipment
  - Primary objective of DETECTS

Design Requirements

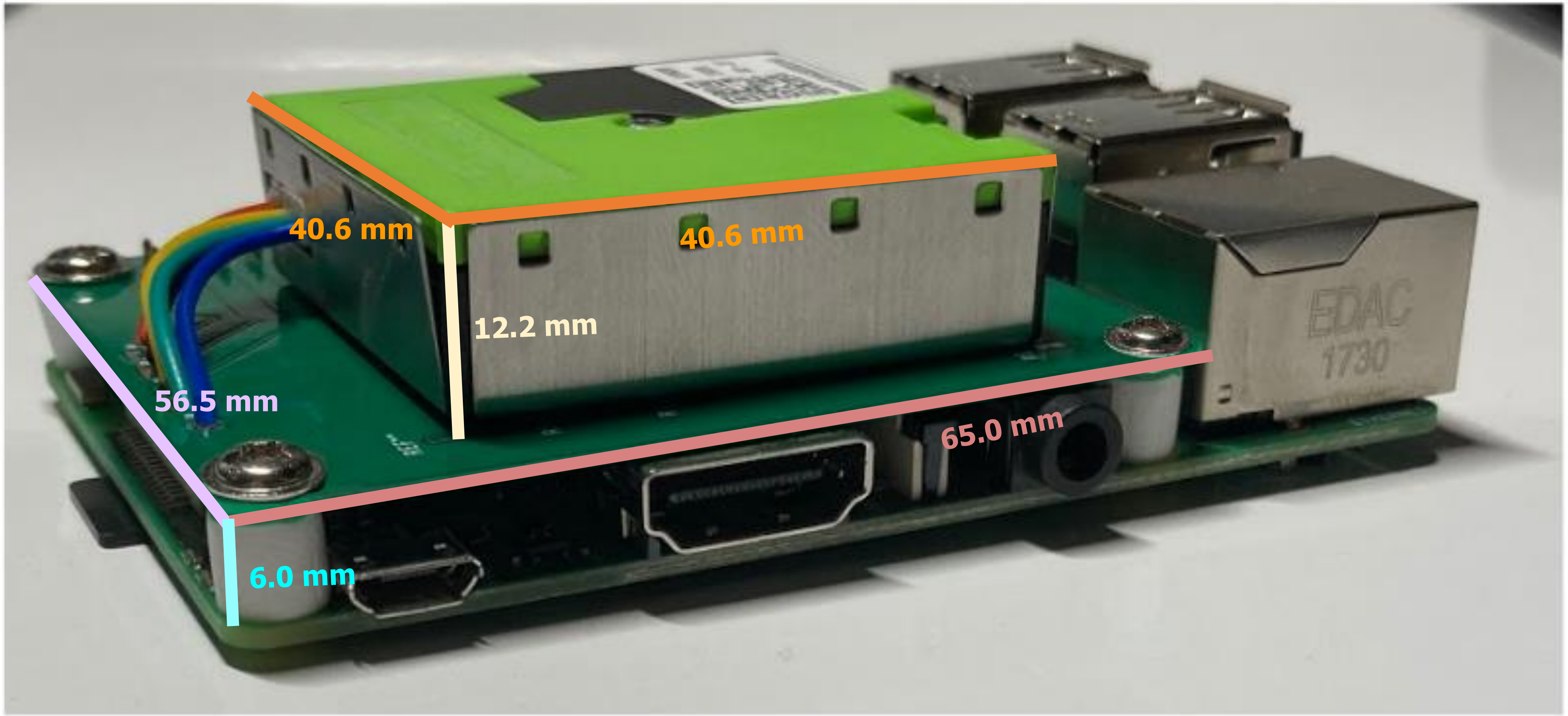
Mechanical/Spatial Requirements	Electrical Requirements
• Must be no larger than 65x56.5mm • Must be less than 19mm above the surface of the Pi when plugged in	• NO High-voltage-inducing instruments (over 28 V) • Pinout used must be the one found on the Pi • Pins 30 and 31 cannot be used
Material Requirements	**Software Requirements**
• NO Mechanisms or moving parts • NO Liquids, gases, or fluids of any kind • NO Organic material or any other exotic material • NO Vibrating/oscillating components • NO Loose/powdered material • NO Batteries or electrolytic capacitors	• Must be developed on a Raspberry Pi 3B+ • Must operate the Pi HAT and gather data from it • Data rate must NOT exceed 5 kilobytes per second • Must communicate with the AR2B flight computer via JSON formatted packets • Transfer JSON packets into a folder called /tmp/experiment/ in the Raspberry Pi's file system • Must include an identifier within the JSON packet

Experiment

Chosen Science Objective

- **Commercial-Grade Contaminants Comparison**
  - Establish an experiment that can compare the quality and quantity of data accumulated from commercial-grade and professional-grade particulate matter sensors.
  - Assess particulate density, prevalence, size, and levels over time in ACES RED 2B using consumer-grade sensors

Experiment Configuration



Concept of Operations

Phase 1
- Powers on (crontab).
- Launches all other programs in a structured order.
- Turn on SPS30; ensure data flow.

Phase 2
- Continuous operation with a 12 hour (on) 2 minute (off) cycle.
- Verifies continuous program functionality with a monitor program.
- Sends data until 14 days before AR2B end-of-life cycle.

Phase 3
- Before AR2B end date, send last packet and poweroff.
- Analyze results.
- Write a report outlining findings.

Testing

Testable Requirements

Functional Requirements
Take Measurements
Organize Data Packets
Send Data
Establish Accurate Particulate Count
Handle Program Errors
Resume Operation After Reboot

Environmental Requirements
Survive Hot Environment
Survive Cold Environment
Survive Extreme Pressures
Survive Random Vibrations
Maintain Structural Integrity

Safety Plan

General Safety Practices

- Use proper Personal Protective Equipment (PPE).
- Have proper emergency equipment available.
- Ensure proper electrostatic discharge (ESD) protection.
- Use ground-fault circuit interrupter equipped (GFCI) outlets.
- Maintain clear and safe lab environment.
- Clean all equipment before and after use.

Hazard Avoidance

- Use N95-mask and fume hood to avoid possible inhalation of fumes.
- Verify equipment works before testing. (fume hood)
- Verify integrity and oil level of vacuum pump before and after use.
- Additional examples of hazard avoidance will be listed under the respective tests.

Functional Test - Transfer Test

Test Overview

- Demonstrates that program can organize and send data packets.
  - Used UAH's and team transfer program.
- Verify data collected is organized and transferred to UAH's data handling program.
  - Test completed 25 times, 0 failures.
  - Pi was rebooted via various stimuli (see Recovery test).

Requirements to Meet

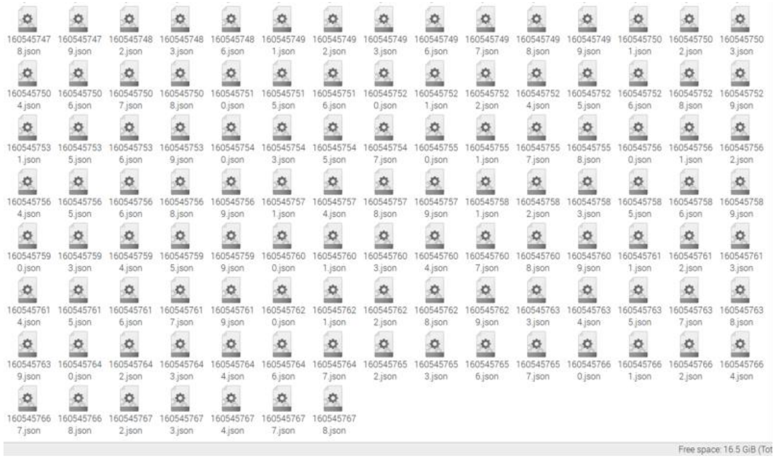
- UAH Requirements:
  - Take measurements, organize data packets, and send data.
  - Data rate of less than **5.0** kBps.
  - Communicate with AR2B flight computer via /tmp/experiment/.

Results

- Pass
- The programs all worked as expected, data was transferred in time stamped files to /tmp/experiment/
  - Max of 0.5 kBps, average of ~0.3 kBps
  - Example from UAH transfer program:

Evidence

- A picture of the populated /tmp/experiment/ folder after a run with the UAH program disabled.



Functional Test - Recovery Test

Test Overview

- Demonstrate that program can handle errors and resume operation at reboot.
- Errors tested: Unplugging SPS30 GPIO data wires, cycling power, killing programs, restarts, shutdowns
  - Test completed 25 times, 0 failures.
  - All program-triggered restarts are called by a monitor program

Requirements to Meet

- UAH Requirements:
  - Take measurements, organize data packets, and send data.
- Team Requirements:
  - Handle program errors
  - Resume operation after reboot

Results

- Pass
- All programs worked as expected, always started back up after reboot.
    - The monitor program was able to detect and recover from all conceived errors.
    - Note: UAH transfer program disabled after successful relaunch to get evidence.

Evidence

- A picture of the populated /tmp/experiment folder after a run with the UAH program disabled.

Functional Test - Sensor Test

Test Overview

- Verify the sensor is accurate and functional.
    - Connected directly to GPIO header
- Verify the sensor can establish an accurate particle count
    - Sensor placed 6 inches above a lighter to measure particulate matter
    - Particulate count was steady, and output matched expected results.

Requirements to Meet

- UAH Requirements:
    - Take measurements, organize data packets, and send data.
- Team Requirements:
    - Establish an accurate particulate count

Results

- Pass
- The programs all worked as expected, data was collected with no errors
    - No errors with I^2C connection
    - Data was accurate
    - Everything functioned as expected

Evidence


```
"id": "PSA Team 1",
"pm0.5 count": "39.22977828979492",
"pm1": "5.615213871002197",
"pm2.5": "5.937880516052246",
"pm4": "5.937880516052246",
"pm10": "5.937880516052246",

"id": "PSA Team 1",
"pm0.5 count": "528.2876586914062",
"pm1": "75.61725616455078",
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"pm4": "79.96244049072266",
"pm10": "79.96244049072266",
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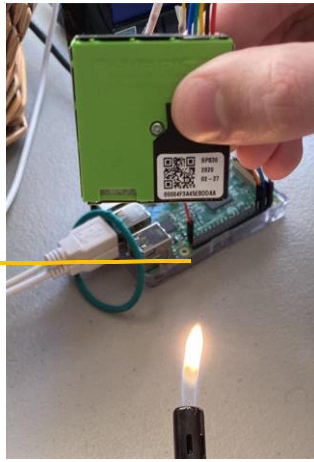


DETECTS

Extreme Heat Testing

Test Reasoning

- Demonstrates that the payload can survive in extreme temperatures.
- Show that the payload can operate and produce accurate data in a heated environment.

Requirements to Meet

- UAH Requirements:
  - Survive up to 90°C.
  - Take measurements, organize data packets, and send data.
- Team Requirements:
  - Survive 90°C for 1 hour.
  - Meet all functional requirements.

Personal Protective Equipment

- Clothing
  - Lab Coat
  - Safety Goggles
  - Heat Resistant Gloves
  - Ground Cable
- Other Equipment
  - Fire Extinguisher
  - Fume Hood

Testing Environment/Plan

- Clean oven before test.
- Test each part of payload (wires, board, SPS30) individually for 1 hour at 90°C.
- Preheat for 30 minutes for assembled test (90°C)
- Test assembled operational payload at 90°C for 1 hour
  - Power with external power source
- Allow to cool to 30°C before handling

Heat Test - Results/Evidence

sensor in freezer

Wires in freezer

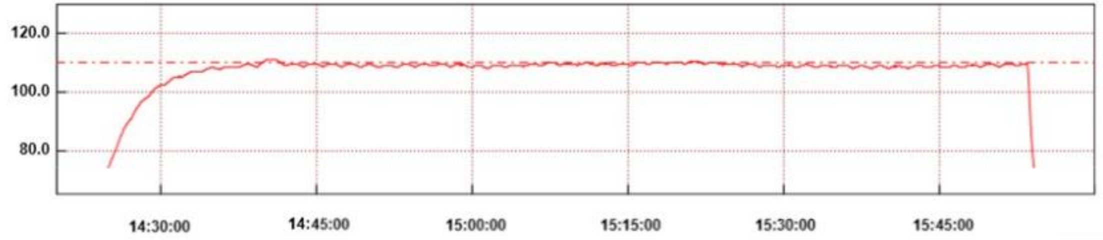
Board in freezer

Full configuration in oven

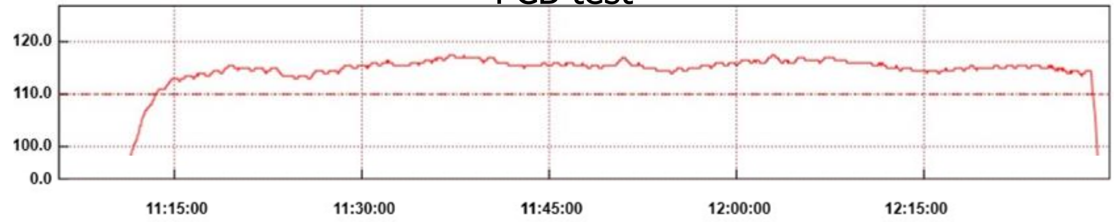
Tester's picture?

Tester's picture?

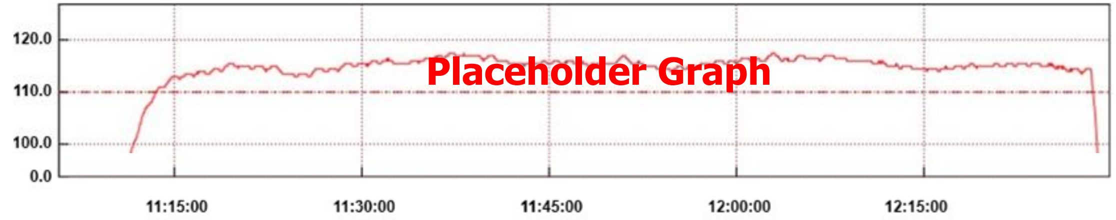
SPS30 (green plastic) test



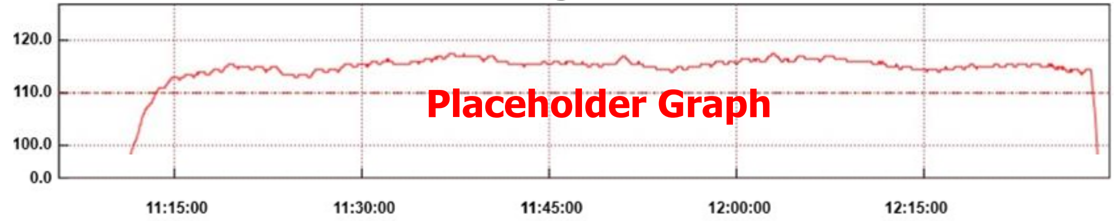
PCB test



Wire test



Full Configuration Test



Extreme Cold Testing

Test Reasoning

- Demonstrate the payload's ability to survive in drastically lower temperatures
- Demonstrates that the sensor will work properly in temperatures as low as -20°C

Requirements to Meet

- UAH Requirements:
  - Survive temperatures as low as -20°C.
  - Take measurements, organize data packets, and send data.
- Team Requirements:
  - Survive -20°C for 1 hour.
  - Meet all functional requirements.

Personal Protective Equipment

- Clothing
  - Lab Coat
  - Safety Goggles
  - Gloves
  - Ground Cable

Testing Environment/Plan

- Set freezer to -20°C, allow 30 minutes to cool.
- Test each part of payload (wires, board, SPS30) individually for 1 hour at -20°C.
- Test assembled operational payload at -20°C for 1 hour.
  - Power with external power source.
- Remove using protective gloves.

Cold Test - Evidence/Results

sensor in freezer

Wires in freezer

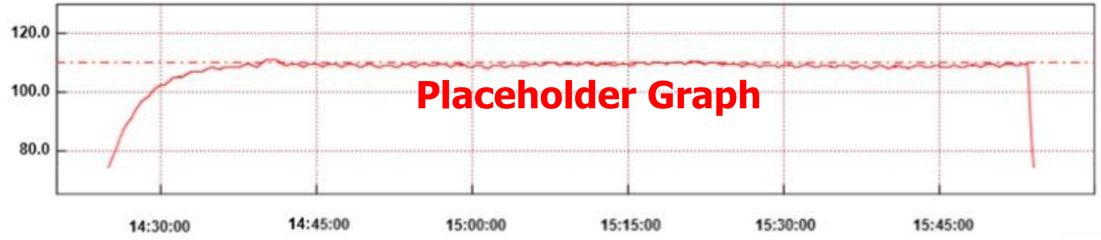
Board in freezer

Full configuration in freezer

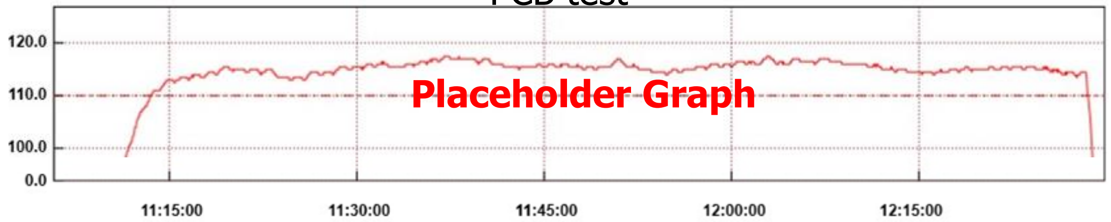
Tester's picture?

Tester's picture?

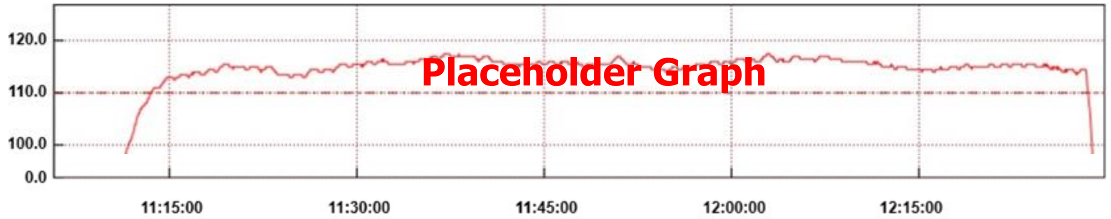
Sensor test



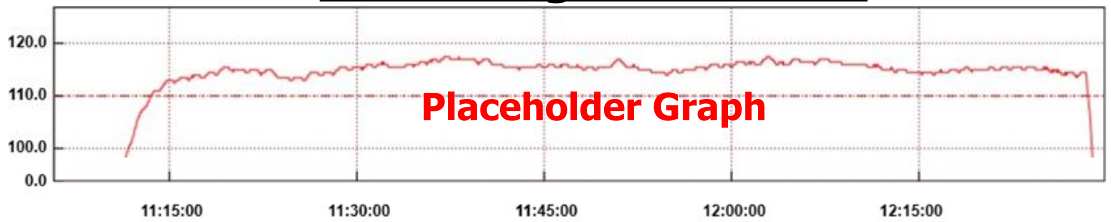
PCB test



Wire test



Full Configuration Test



Random Vibration Testing

Test Reasoning

- Demonstrate that the payload can survive and operable while experiencing random vibrations

Requirements to Meet

- UAH Requirements:
  - Survive random vibrations up to 4 gs.
  - Take measurements, organize data packets, and send data.
- Team Requirements:
  - Survive 4 gs for 1 hour.
  - Survive random vibrations.
  - Meet all functional requirements.

Personal Protective Equipment

- Clothing
  - Lab Coat (for in lab)
  - Insulated Gloves
  - Ground Cable

Testing Environment/Plan

- Check integrity of parts beforehand
- Place in centrifuge to place experiment under high G forces
  - 1 hour of continuous unidirectional acceleration.
- Bumpy South Carolina back roads
  - 30 minutes of random but gentler acceleration.
- Vigorously shake pi by base
  - 15 minutes of extreme random acceleration.

Vibration Test - Evidence/Results

Misc Picture

Misc picture

Testers Shaking payload

Config in centrifuge

Car Data

Shaking Data (might be weird looking)

Centrifuge Data

Gravel Lot by CSC

Mounte
d
payload

Vacuum Testing

Test Reasoning

- Demonstrate that the payload can maintain structural integrity and remain operable in vacuum-like conditions

Requirements to Meet

- UAH Requirements:
    - Survive vacuum.
    - Take measurements, organize data packets, and send data.
- Team Requirements:
    - Survive 4 gs for 1 hour.
    - Survive random vibrations.
    - Meet all functional requirements.

Personal Protective Equipment

- Clothing
    - Lab Coat (for in lab)
    - Insulated Gloves
    - Ground Cable
    - Safety Goggles
- Equipment
    - Fire Extinguisher
    - GCFI protected outlet
    - Other UAH guidelines?

Testing Environment/Plan

- Change oil and inspect vacuum chamber for defects
- Test each part of payload (wires, board, SPS30) individually for 1 hour.
    - Follow steps in vacuum testing handout.
- Test assembled payload with battery for 30 minutes.
- Allow repressurization of chamber, and repeat test.

Vacuum Test - Evidence/Results

sensor in vac chamber

Wires in vac chamber

Board in vac chamber

Config in Vacuum Chamber

Full setup with pump in frame

Testers

Particulate Data - Test 1

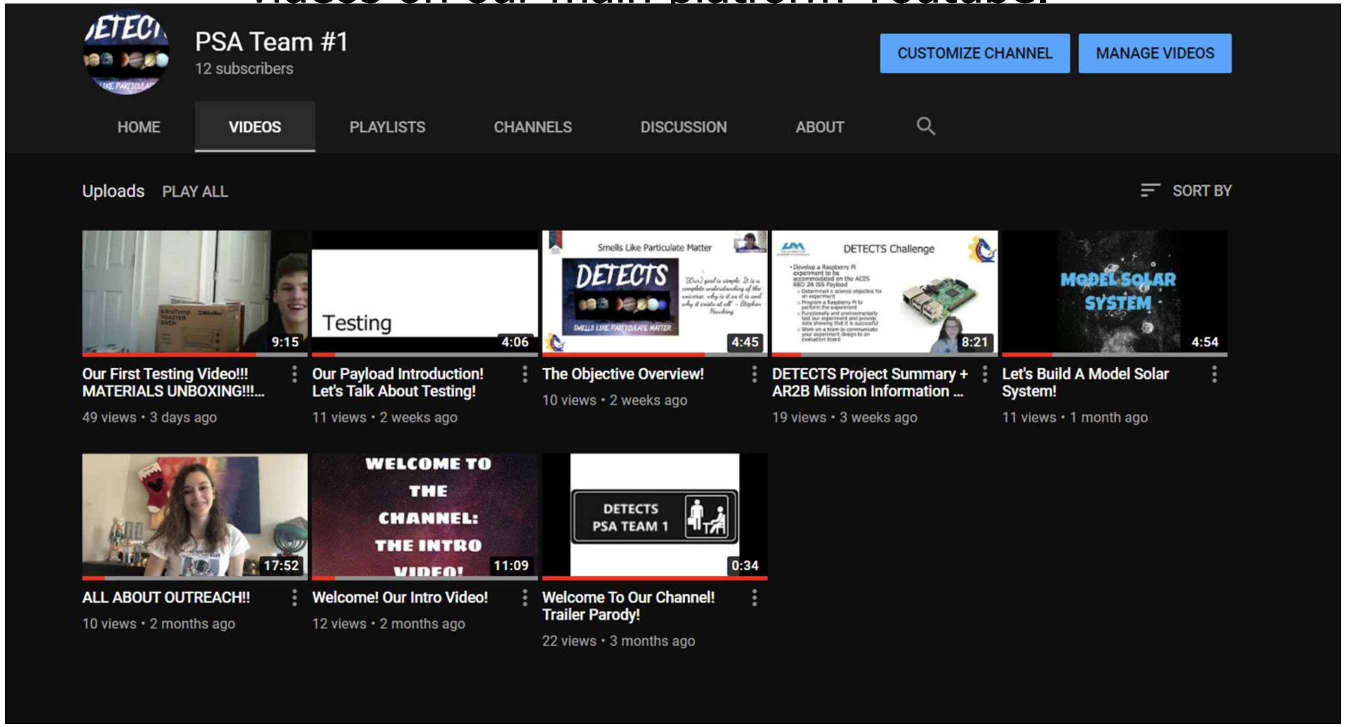
Particulate Data - Test 2

Particulate Data - Test 3

Online Outreach

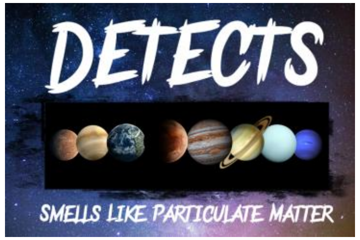
Outreach Plan

Our goal, as a team, is to create an online presence to engage and inform viewers about DETECTS and our team. This will be done by sharing both informative and fun videos on our main platform Youtube.

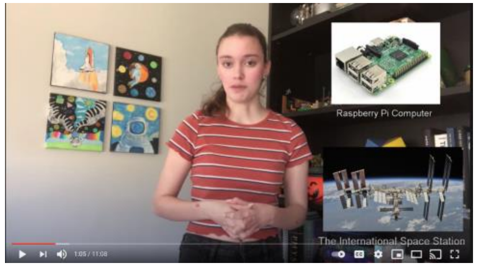


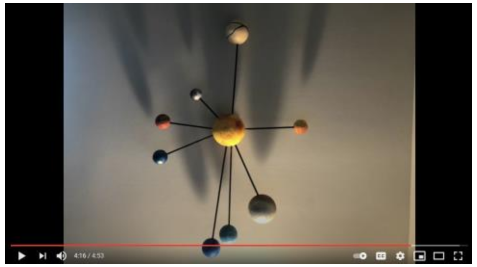
Our platform choice was based on our contents topic, targeted demographic, team dynamic, ability to have creative freedom, and the popularity of the platform.

Outreach Content So Far



Date	Title	Content Requirement
October 26th, 2020	*Channel Trailer*	None ~Added By Our Team~
November 21st, 2020	*General Introduction Video*	DETECTS Project Summary
December 13th, 2020	*All About Outreach*	None ~Added By Our Team~
December 19th, 2020	*Let's Build A Model Solar System*	Activity/Demonstration related to our Objective
January 23rd, 2021	*DETECTS Project Summary + AR2B Information*	DETECTS Project Summary AR2B Mission Overview
January 30th, 2021	*The Objective Overview!*	Potential Science Objectives Selection Process Visual Demonstration/Explanation for Experiment Design
February 3rd, 2021	*Payload & Testing Introduction*	Summary of Design Process Explanation of the Testing Process
February 15th, 2021	*Testing Video #1: Materials Unboxing!*	None ~ Added By Our Team~





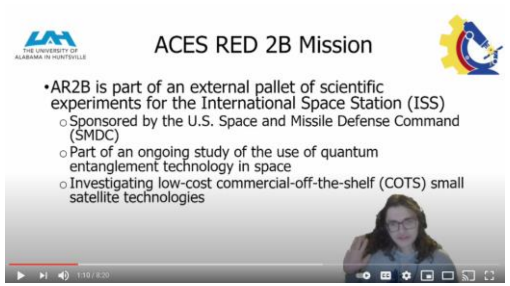
Color Key	
(green)	Activity Or Demonstration Video
(blue)	Discussion Or Presentation Style Video
(pink)	Video Topic Created By Our Team

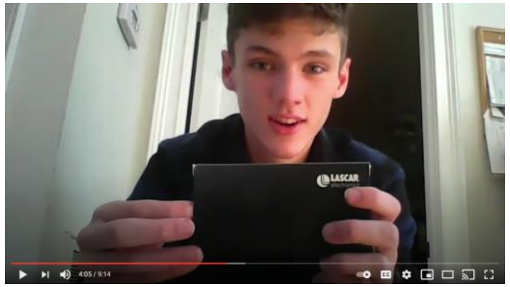
Planned Outreach Content

Upcoming Videos		
Date	**Title**	**Content Requirement**
February 27th	*Payload Breakdown*	Summary of Design Process - Image + Description content Demonstration For Pi

February 27th	*Testing Video #2*
	- *Sautering*
	- *Thermal Testing*
	  - *Heat Test*
	  - *Chill Test*
	- *Functional Testing*
		Explanation of
		- Functional Testing
		- Thermal Testing
		Functional & Thermal Testing Content
		Demonstration For Testing + Pi

March 6th, 2021	*Testing Video #3* - *Vacuum Test* - *Rumble Test*	Explanation of - Vacuum Testing - Vibration Testing Vacuum Testing Content Vibration Testing Content Demonstration For Testing
March 13th, 2021	*Testing Result Analysis + Data!*	Data Analysis
March 20th, 2021	*Project Summary*	Project Summary
March 27th, 2021	*Project Pros & Cons + Lessons Learned*	Pros & Cons Lessons Learned
April 3rd, 2021	*Q + A Video*	None ~Added By Our Team~
April 10th, 2021	*How We Prep For Final Review*	None ~Added By Our Team~
April 17th, 2021	*Thank You Video - A Message To Our Viewers*	None ~Added By Our Team~





Sensor Problems

Sensor Problems

<u>The Problem</u>

SPS30 datasheet says temperature limits of SPS30 are **-10°C** to **60°C**

<u>The Solution</u>

Identify limiting component(s), remedy problem.

#1 - Internal Fan
#2 - Plastic Components

These are not the only ideas I have considered, just the ones worth mentioning. I would really appreciate any thoughts or other ideas you may have on the subject!

Excellence and Innovation

Palmetto Scholars Academy

DETECTS

SMELLS LIKE PARTICULATE MATTER

Problem - Internal Fan

After hours of searching and thinking, I think I finally figured out the problem.

The SPS30 has a thermal limitation of -10°C to 60°C.

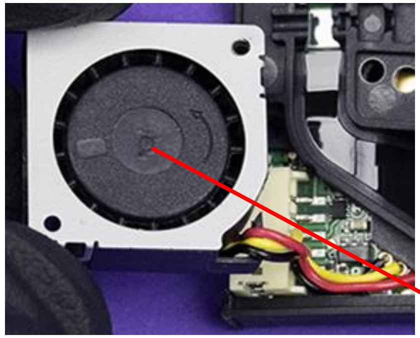
I was not able to find the datasheet for the exact model fan used in the SPS30 (MF20060V2-1C010-G99)

The SPS30's internal fan has a thermal limitation of -10°C to 70°C.

During thermal testing (by the fan manufacturer) of similar internal fans, they only tested their fans at 70°C for 2 hours, and they reported decreased efficiency near temperature extremes
(~5 to -10, and ~55 to 70).

4. THERMAL CYCLING TEST

The fan is operated in a testing chamber for 50 cycles. In each cycle, the temperature is gradually increased from -10°C to 70°C for 90 minutes, and subsequently operated at 70°C for 120 minutes. The temperature is then gradually decreased from 70°C to -10°C for 90 minutes, and subsequently operated at -10°C for 120 minutes.



OPERATING TEMPERATURE RANGE	**-10 to + 70 deg. C**
STORAGE TEMPERATURE RANGE	**-40 to + 70 deg. C**

DETECTS

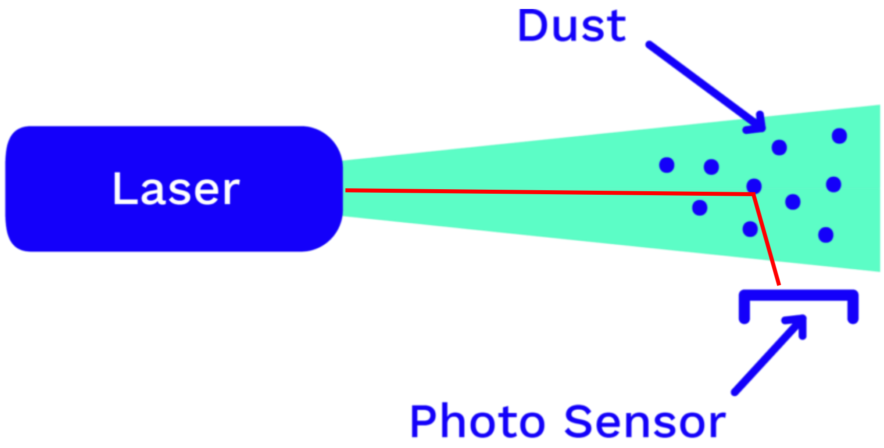
Solution - Internal Fan

In a vacuum, a fan has no purpose.

I already created a call to disable the fan when I created the sensor interface program last semester.

The fan itself is still inside of the SPS30, but its can be disabled both physically and digitally.

The SPS30 does not need a fan to function, rather, it facilitates the transport of particles into the sensor. In addition, the payload will be in an enclosed environment, in microgravity, in vacuum conditions, where there will be no need for an additional catalyst of particle movement.



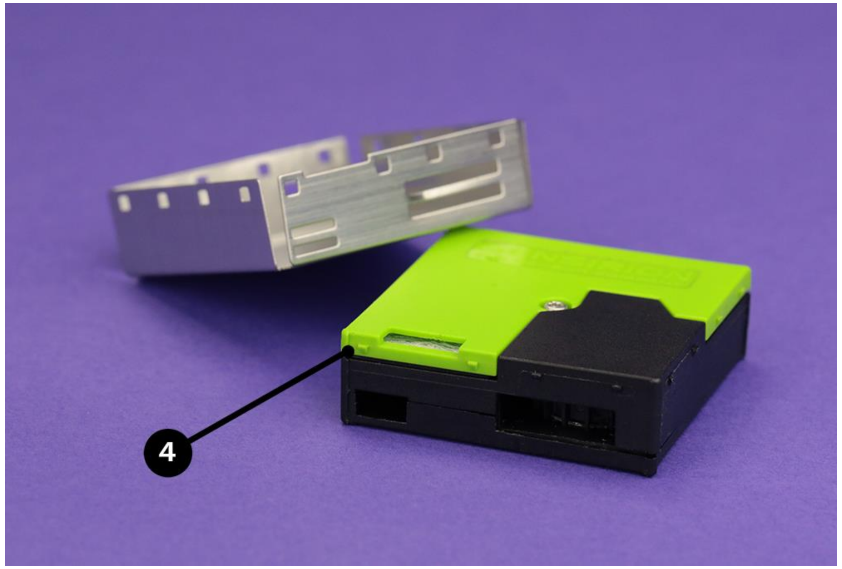
Plastic Components

The SPS30 is almost entirely plastic components, and I was initially worried that they might deform under heat.

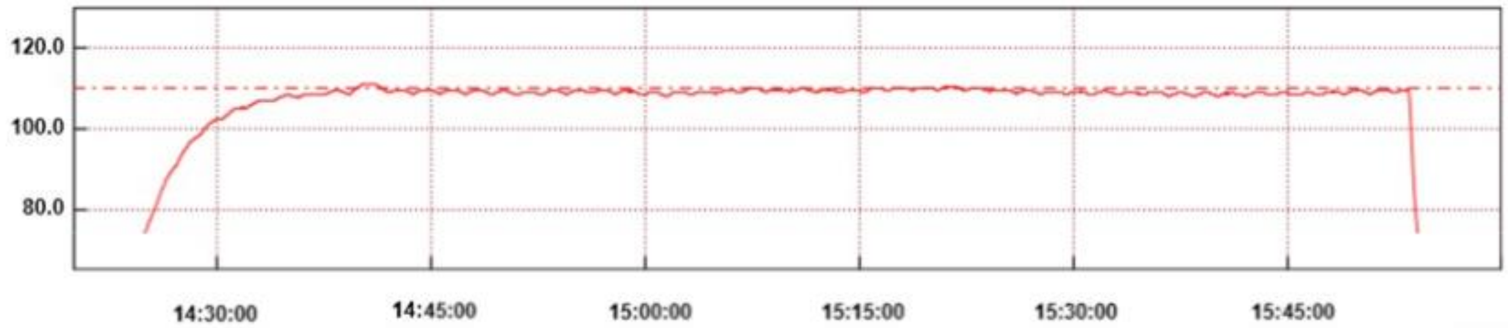
When I took the top green piece of plastic off the SPS30, it looked very solid and I decided to test it.

It survived the oven at 110°C for ~1:15, leading me to believe that the plastic is not the problem.

The plastic fit normally back into place on the sensor, no problems were noted.



SPS30 (green plastic) test



Solution - Plastic Components

If the plastic components prove to still be a problem, we can still work around this.

The SPS30 comes apart completely into PCB, laser, and plastic pieces, respectively.

We can complete a 3D scan of all of the plastic pieces and convert that scan into a CAD model. There are services that will do this professionally and there are also applications that turn photo/video into a CAD model.

We can then reprint the pieces with a more heat resistant material like nylon, aluminum, etc.