



Solar Panel Characterization on Stratospheric Balloon Flights

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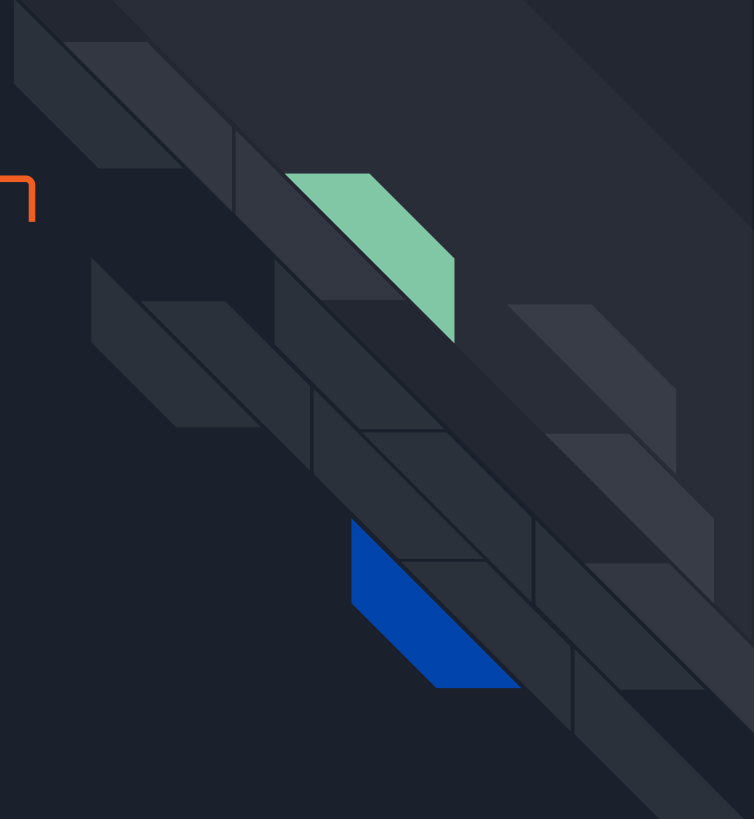
Background Information

Hypothesis

Methods

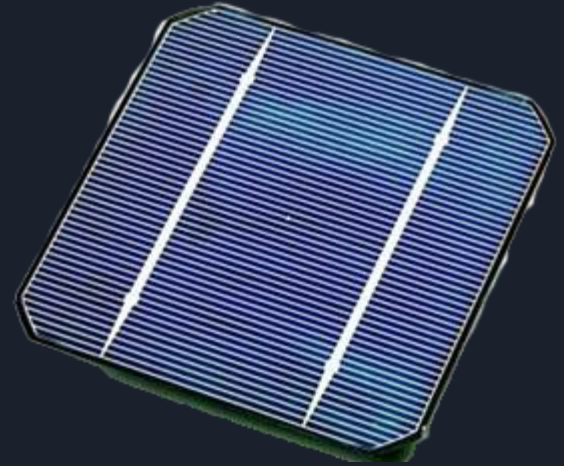
Results

Future Impacts



Where the Project Came From

- Batteries we use are single use
- Energy from sunlight is available during a flight
- Solar panels give varying amounts of power
- Solar panel power production model would help
- Focused on temperature and light intensity





Why Solar Panels?

- At -20° Celsius (-4° Fahrenheit) many 9 volt batteries are at about 50% performance level
- Solar panels could reduce the number of batteries needed
- The efficiency of solar panels typically improves with altitude

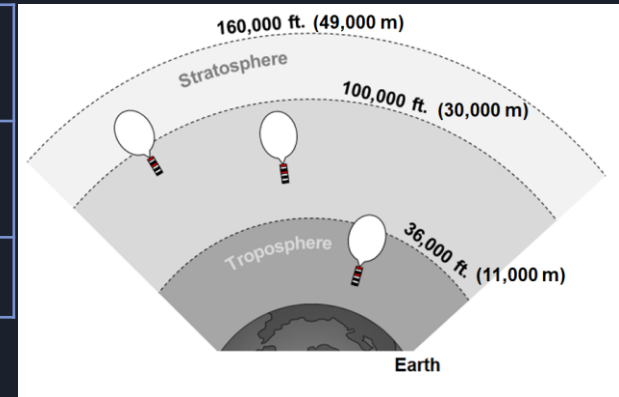
Known Environmental Characteristics

A simple model of atmospheric temperature vs altitude above sea level:

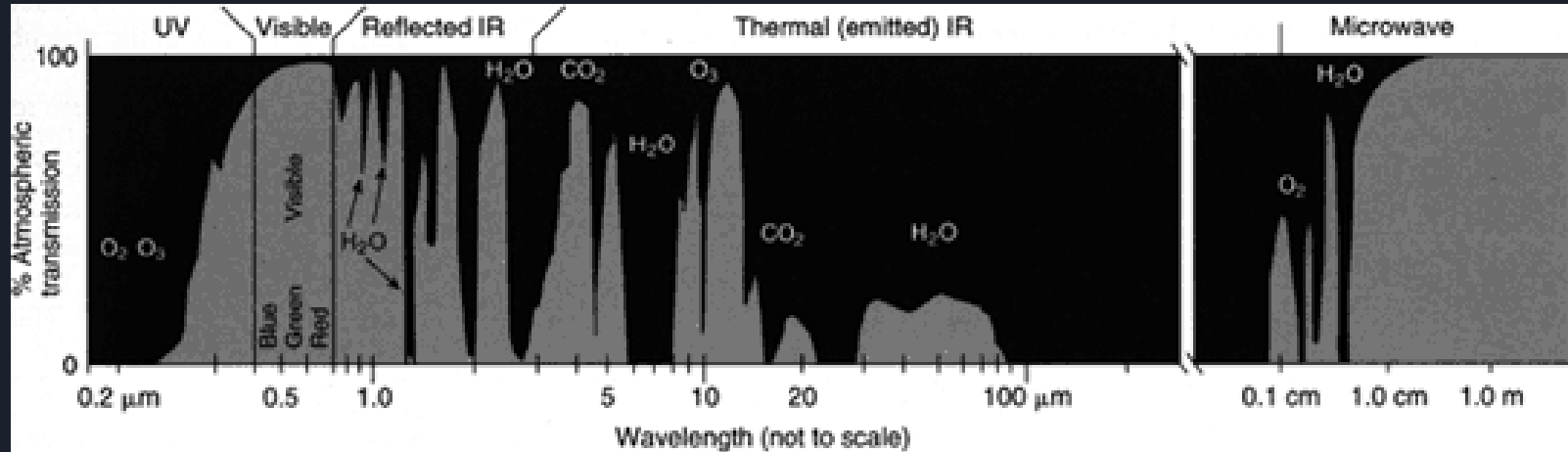
For $h^* > 25,000$ (Upper Stratosphere)	$T^{**} = -131.21 + 0.00299 h$
For $11,000 < h < 25,000$ (Lower Stratosphere)	$T = -56.46$
For $h < 11,000$ (Troposphere)	$T = 15.04 - 0.00649 h$

*Altitude h is in meters

**Temperature T is in degrees Celsius



Known Environmental Characteristics cont.



This figure shows that radio light and most visible light penetrates the atmosphere (i.e. reaches the ground), but other types of light are attenuated, often severely. A balloon flight gets above much of the atmosphere so solar panels are exposed to more intense light in many wavelengths.




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Hypothesis

H_1 :

As the **altitude** of a balloon **increases**, the power produced by a **solar cell** will also **increase**.

Other experimental questions:

1. How much does **atmospheric temperature** change the power output of a solar cell?
2. How much does **light intensity** change the power output of a solar cell?

Null Hypothesis

H_0 :

As the **altitude** of a balloon **increases**, there will be **no statistically significant impact** on the power produced by a **solar cell**.

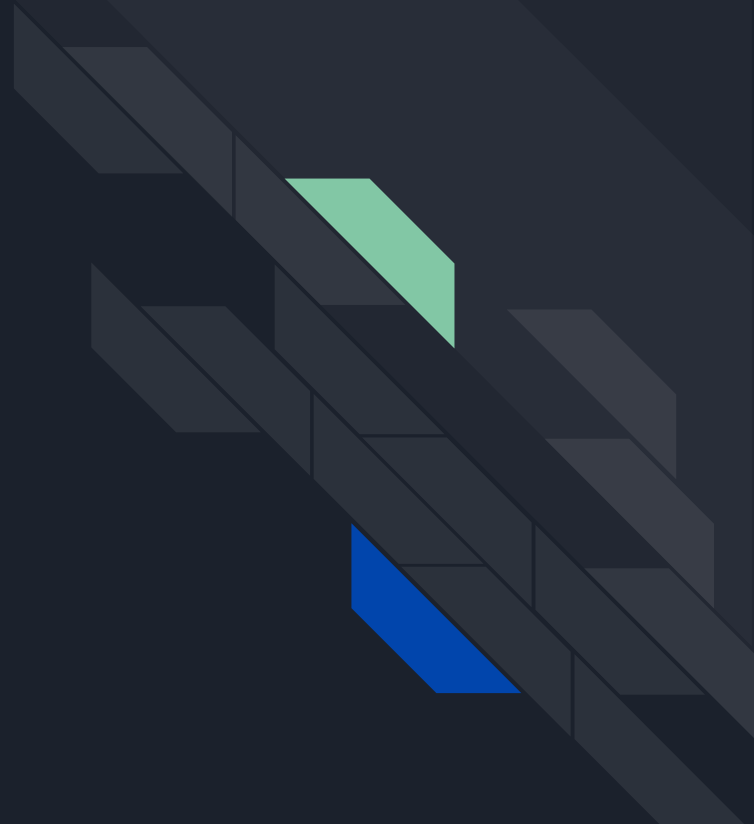
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- a. The Payload
- b. The Tests

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Payload Setup

1. Louvre Mechanism
2. Mesh Heating Unit
3. “Enclosed Solar Panel”
(actively heated)
4. “Exposed Solar Panel”
(unheated)



Payload Setup cont.

5. Temperature Sensor for “Enclosed Solar Panel” (used to control heater)
6. Temperature Sensor “Exposed Solar Panel” (just logging)
7. Acrylic Cover
8. Power Switch
9. OLED Live Data Display



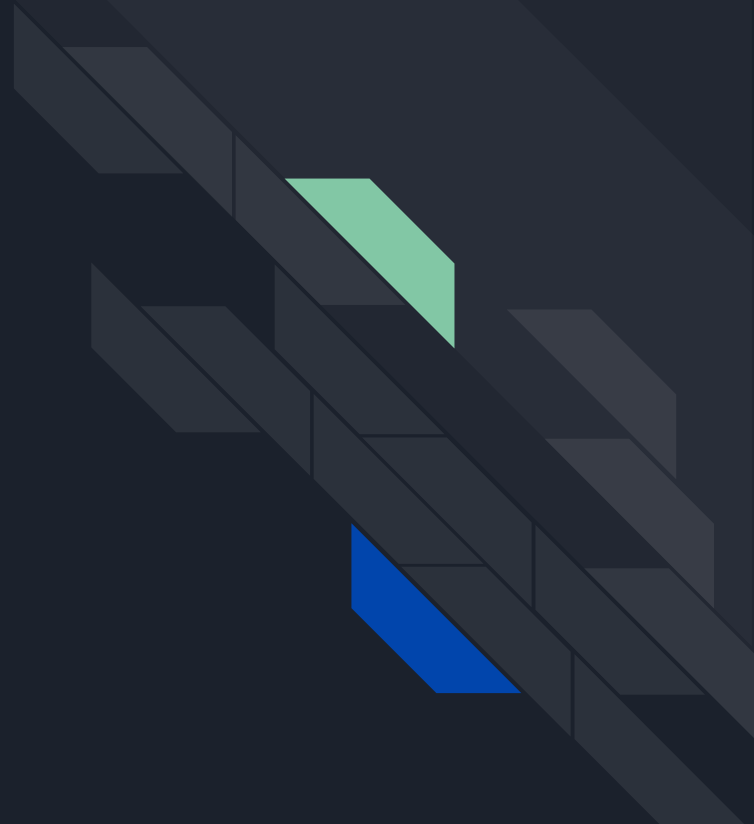
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Ground Testing

- Cold Soak tests
 - Placing testing materials in a -30°C environment
- Sunlight tests
 - Placing the payload in direct sunlight on the ground (watch for overheating)
- Solar panel testing
 - Placing solar panels in direct sunlight and comparing their output



Cold Soak Box. Dry Ice was placed on the walls. A window allowed light in.

Flight Testing

GL129: Two Arduinos were used which caused problems that led to both shutting off ~20 minutes into the ascent

GL130: Temperature overheated, reaching 60°C in the “enclosed” environment (i.e. not constant temp.)

GL132: The “exposed” solar panel output rose above the 5 volt limit of the Arduino Mega analog input




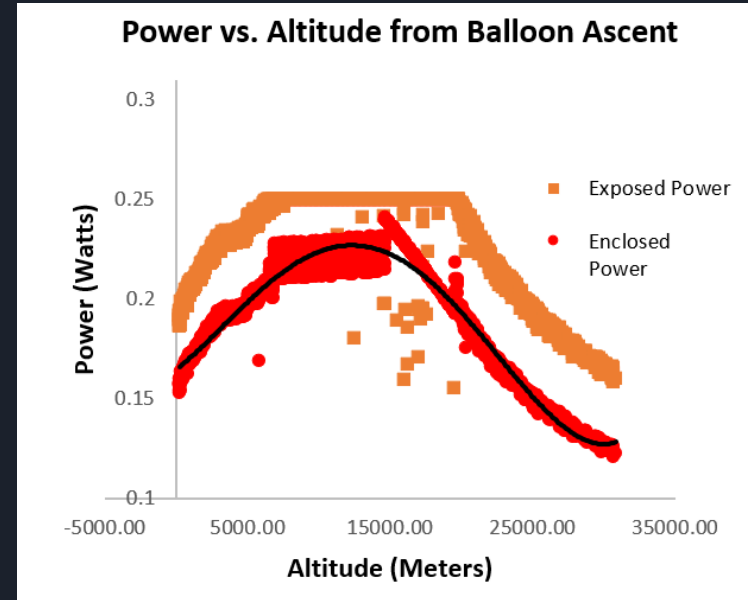


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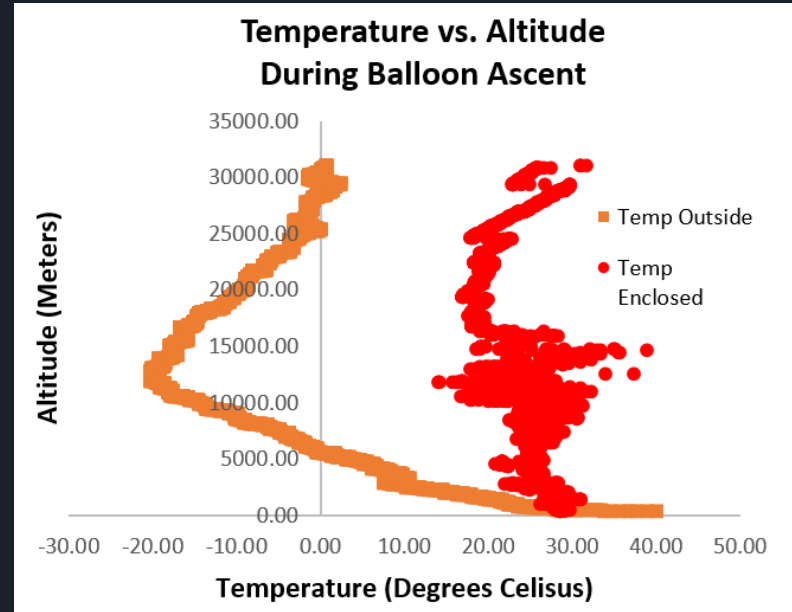
Power Versus Altitude

- The voltage readings rose above 5 volts which is above an Arduino's analog input max
- The “exposed” solar panel produced more power (which was expected)
- Once in the stratosphere the power production decreased (more than expected)
- The power output at the highest altitude is lower than the power output at launch (unexpected)
- At launch, the temperature was different in both environments



Temperature Versus Altitude

- The “exposed” solar panel’s temperature followed the standard (ambient temp.) pattern
- The “enclosed” solar panel’s temperature was held somewhat constant with the heater/louvre system



Power Versus Temperature

On Ascent

- “Strange” power data (ascent only)
- 2 distinct trends seen in power production as altitude increases
 - Dropping temperature and increasing power (eventually saturated) up to the tropopause
 - Increasing temperature but unexpectedly low power during continued ascent in stratosphere
- Has anyone else seen something like this before?

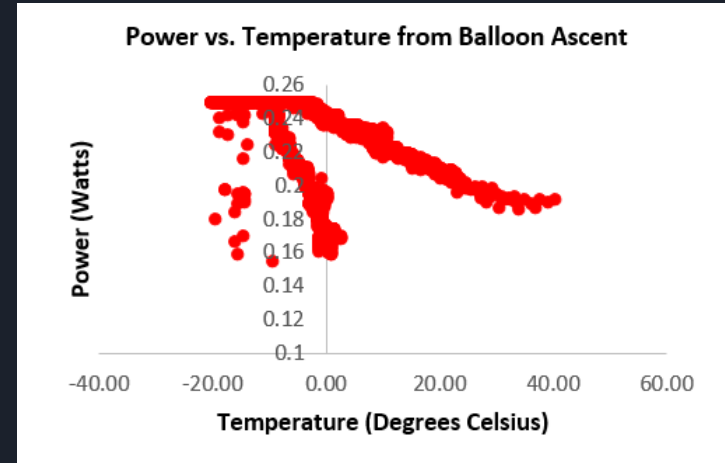




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Future Challenges

- We need to do more testing, to explore unexpected results
- Add voltage divider on solar panel input lines to avoid saturation of Arduino analog input
- Proposed software improvements
 - Adjust heater/louvre/temperature sensor logic to try to hold “enclosed” chamber at a more-constant temperature
 - Calculate altitude based off of temperature and pressure
- Neither hypothesis H_1 nor H_0 can be confirmed (yet)



Future Benefits

- Lighter payloads
- A potential to fly longer
- Reliable power sources
- Fewer batteries used
- The ability to reliably use solar panels
- Solar powered payloads (even if not required for 2-hour flights, developing this is educationally valuable - more like outer-space missions)

Questions?

