GRASP; OIT-W
Preliminary Design Review

Oregon Institute of Technology
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Mickie Cassady
Kevin Malstrom
Eric Shaw-Stearns

10/10/2016
PDR Presentation Contents

- Section 0: Quick Updates
- Section 1: Mission Overview
  - Mission Statement
  - Mission Objectives
  - System Requirements
  - Success Criteria
  - Theory and Concept
  - Expected Results
  - Concept of Operations
  - Functional Requirements
PDR Presentation Contents

• Section 2: System Overview
  – Subsystem Definitions
  – System Level Block Diagram
  – Physical Model
  – Ports
  – User Guide Compliance
  – Shared Can Logistics
PDR Presentation Contents

• Section 3: Subsystem Design
  – Battery and Power
    • Block Diagram
    • Risks
    • Risk Matrix
  – Sensor Suite
    • Block Diagram
    • Risks
    • Risk Matrix
PDR Presentation Contents

• Section 3: Subsystem Design (cont)
  – Optical Port
    • Block Diagram
    • Trade Studies
    • Risks
    • Risk Matrix
  – Sensor Suite
    • Trade Studies
    • Risks
    • Risk Matrix
PDR Presentation Contents

- Section 4: Testing / Prototyping Plan
- Section 6: Project Management Plan
  - Org Chart
  - Team Schedule
  - Schedule Beyond CDR
  - Overarching Budget
  - Parts Budget
  - Team Contact Matrix
  - Team Availability Matrix
  - Concerns
  - Conclusion
Section 0: Updates from CoDR

- HAM Radio is no more
- Held a teleconference with WV
- Geiger Counter current for Wallops
Mission Overview

Mickie Cassady
Mission Statement

GRASP’s goal for this project is to measure the electromagnetic (EM) exposure and solar behavior of a solar cell in the mesosphere and thermosphere.
GRASP RockSat-C Mission Objectives

• Objectives:
  – Affix solar cells and spectrometer to payload to maximize exposure to electromagnetic waves in the mesosphere and thermosphere.
  – Measure the short circuit current and open circuit voltage of the solar cell using onboard sensors.
  – Calculate fill factor and max power out.
  – Compare calculated fill factor max power to collected spectrometer data to determine relationship.
GRASP RockSat-C System Requirements

• System Requirements
  – Access to optical port for solar cell and spectrometer
  – Onboard equipment which includes gyroscope, accelerometers, and a temperature sensor, needs to be able to measure current/voltage.
  – SD card for data storage

• Minimum Success
  – Voltage and current successfully measured, stored, and graphed for interpretation.
  – Spectrometer data properly collected, stored, and displayed for interpretation.
Comprehensive Success Criteria

• Ideal mission requirements:
  • Measurement of voltage and current data that allow for calculation of Pmax and Fill Factor
  • Collection of spectral data that can establish a correlation between measured light intensity and calculated Pmax and Fill Factor.
• Solar cell power output is heavily based on EM. The spectrometer will determine what kind of radiation the cell is receiving.
• Upper atmosphere contains gamma radiation which is known to reduce solar cell performance.
• Solar cell performance can be measured with maximum power (Pmax) output and Fill Factor.
Mission Overview: Theory and Concepts

• Pmax output is the highest calculated power (current*voltage) in a V-I graph.
• Fill Factor (FF) is max power divided by voltage times current.
• Microcontrolled sensors will measure voltage and current for max power and FF calculation.
• Pmax and FF will be compared to gamma radiation levels to obtain correlation.
Mission Overview: Theory and Concepts

Previous Research

• Old Dominion University launched similar RockSat-C project in 2015 with emphasis on transmitting the data to a ground station.
  – Results from final report showed successful collection but did not show mission Pmax and FF.
  – We will differentiate with inclusion of spectrometer and emphasis on solar cell calculations.
Mission Overview: Expected Results

• We expect to see a periodic pulse pattern waveform for the current and voltage measurements due to spinning rocket.
• We expect to see a reduced $P_{max}$ and $FF$ from standard testing conditions depending on which type of cell we select.
Mission Overview: Concept of Operations

- The payload will begin collecting before or at launch, depending on the microcontroller used.*
- Special altitudes of interest will include 50km and 80km from sea level as these are traditionally the boundaries for the mesosphere and thermosphere.
- The payload will continue to collect data until retrieval or until the SD card is filled.

*Point to be brought up in “concerns”
## Functional Requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The solar cell shall produce measurable voltage and current readings once</td>
<td><strong>Demonstration</strong></td>
<td>Visible light will be directed to optical port while payload is powered to</td>
</tr>
<tr>
<td>fixed on payload.</td>
<td></td>
<td>measure current and voltage.</td>
</tr>
<tr>
<td>The payload shall measure the open circuit voltage and short circuit current</td>
<td><strong>Demonstration</strong></td>
<td>The system will be powered on to verify the measurement of these parameters.</td>
</tr>
<tr>
<td>of the solar cell.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The spectroscope shall obtain light intensity data from the optical port.</td>
<td><strong>Demonstration</strong></td>
<td>Varying types of visible light will be shown on scope to verify scope’s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>collection of intensity data.</td>
</tr>
<tr>
<td>The data shall be stored on the SD card and easily recovered without loss.</td>
<td><strong>Demonstration</strong></td>
<td>Data from previous demonstrations will be pulled from SD card and accessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to verify integrity.</td>
</tr>
<tr>
<td>The stored data shall be robust and consistent enough for a graphical display</td>
<td><strong>Analysis</strong></td>
<td>Pulled demonstration data will be plotted and displayed on laptop.</td>
</tr>
<tr>
<td>for interpretation.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
De-Scopes & Off-Ramps

• If spectroscope proves too pricey (>\$3,500) to purchase and effectively integrate into payload, a series of photoresistors shall be fixed around solar cells to detect light intensity of visible light range.
• If appropriately small (<0.5” width or length) multicrystalline cannot be obtained, several monocrystalline cells of varying chemical compositions will be substituted.
System Overview

*Eric Shaw-Stearns*
Mechanical Engineering Lead

*Kevin Malstrom*
Electrical Engineering Lead
System Definitions

- Our major subsystems include:
  - Battery & Power Regulation
  - Sensor Suite
    - Geiger Counter
    - Temperature Sensor
    - Humidity Sensor
    - Accelerometers
  - Optical Port
    - Digital Spectroscope & Probe
    - Solar Panel, Voltage & current measuring circuitry
  - Raspberry Pi
System Design – Physical Model

*All Units in Inches*

- **RaspPi**
  - 3.35 X 1.93 X 0.75

- **LIPo**
  - 4.13 X 1.38 X 1.02

- **PCB**
  - 3.6 X 2.25 X 0.75

- **PV Array & Sensor Mount**
  - 2.5” H
  - Inner R2.0
  - Outer R2.2

RockSat-C 2017

PDR
Physical Model (continued)

*All Units in Inches*

- LiPo: 4.13 x 1.38 x 1.02
- RaspPi: 3.35 x 1.93 x 0.75
- PV Array & Sensor Mount: 2.5" H
  - Inner R2.0
  - Outer R2.2
- Spectroscope: 3.74 x 2.68 x 0.79
Physical Model (continued)
Physical Model (continued)

*All Units in Inches*

Payload Over 2'
4.75’ w/ Array
3.25’ w/ Out

2” Stand Off
*Mounted to Lid*

2.5” Array Height
Design Overview: Ports

• We have requested access to one optical port for our half of the payload
  – In our collaboration with West Virginia we have requested two ports total - one for each team.
• The port will be used to expose our solar cell and spectrometer to external radiation.
Design Overview: User’s Guide Compliance

- Predicted mass – <7 pounds
  - Our collaboration with West Virginia precludes an accurate prediction at this time
- Our canister will be shared with West Virginia SPACE Collaboration and our project will occupy one half of the total space.
- Utilizing a microcontroller, we will implement g-switch activation as well as a redundant activation system*

*Point to be brought up in “concerns”
Design Overview: Shared Can Logistics

• West Virginia SPACE Collaboration
  – “Fly science payload in space environment to enhance domain knowledge of next generation engineers and scientists”

• Plan for collaboration
  – Emailing this far with their team lead
  – Phone numbers have been shared for short notice questions.
  – Held a teleconference, at least one more before CDR also
  – Each mechanical lead has contact information for one another

• We will mount to the lid - No mid mounting plate
• Top half of the canister
• We both need optical ports
• *Team is subject to change if we can’t share the canister with two ports.*
Subsystem Design
Battery & Power Regulation

Kevin Malstrom
Battery & Power Regulation

• We will be using a Lithium-Polymer Battery as our power source. For power regulation, we will use either an off-the-shelf voltage regulator, or (time and resources permitting), a custom designed IC incorporating both this subsection, the sensor suite, & the Voltage & Current Measurement circuitry.
• The exact capacity of the battery will be determined during the prototyping phase, once more precise power demands have been established.
Battery & Power Regulation: Block Diagram

Legend

- Signal connection
- Signal / Low Voltage Power
- Low Voltage
- High Voltage

Battery → G-Switch → RBF (Wallops) → Low-Voltage Power supply → High-Voltage Power Supply
Battery & Power Regulation: Risks

BPR.RSK1
The only significant risk for this subsection is the availability of an over-the-counter power supply to provide the voltage required for the geiger counter.

BPR.RSK2
If an over-the-counter power supply is unavailable, we will either re-use the geiger counter from our previous payload, or use the schematic as part of a custom PCB.
Battery & Power Regulation: Risk Matrix

BPR.RSK1

BPR.RSK2
Subsystem Design
Sensor Suite

Kevin Malstrom
This subsystem will either:

- incorporate a number of over-the-counter, solid-state sensors soldered onto a motherboard PCB.
- Combine several sensor elements into a custom-designed PCB as a hat for the Raspberry Pi.
Sensor Suite: Block Diagram

Sensor Suite

- Geiger Counter
- Temperature / Humidity Sensors
- Accelerometers
Sensor Suite: Risks

SS.RSK1
There will be physical data loss using over the counter sensors.

SS.RSK2
There will be design error and lengthened development time using a PCB.
Sensor Suite: Risk Matrix

SS.RSK1

SS.RSK2
Subsystem Design

Optical Port

Kevin Malstrom
Optical Port Design Section

- Depending on physical constraints and required exposure times, we will be angling multiple panels to test different types of solar cells.
- The voltage and current measuring circuitry will likely require a custom PCB, exporting data to the Raspberry Pi.
- The spectroscope will export data to the Raspberry Pi, and be synchronized with the other sensor data to account for changes in performance stemming from all significant environmental factors.
Optical Port: Block Diagram

- Optical Port
  - Spectroscope Probe
  - Solar Cell(s)
  - Voltage & Current Measuring Circuitry
  - Digital Spectroscope
Optical Port: Trade Studies

- Our current branch point our design revolves around determining the relevant wavelength(s) of light that can be used by our cells. Our prototyping findings may show the need for either a simple photo-resistor array, or a more comprehensive spectroscope and probe. Our choices will be driven almost exclusively by the requirements of the data.

<table>
<thead>
<tr>
<th>Device Option</th>
<th>Spectroscope</th>
<th>Photo-resistor array</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Accuracy</td>
<td>10</td>
<td>Unknown</td>
</tr>
<tr>
<td>Response rate</td>
<td>10</td>
<td>Unknown</td>
</tr>
<tr>
<td>Simplicity</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>
Optical Port: Risks

• Our current design allows for a range of potential solar cells, which will be selected during the prototyping phase. The most significant risks are:
  - SS.RSK1: The cost of the spectroscope is prohibitive, forcing a re-design.
  - SS.RSK2: That the solar cells are too large to use position multiple versions.
Optical Port: Risk Matrix
Subsystem Design
Raspberry Pi

Kevin Malstrom
• Our design will be controlled with a Raspberry Pi, which will incorporate all of the sensor data, timestamp each data sample, and record the data to an SD card for storage.
• Depending on the number of analog signals to be measured, secondary ADCs (Analog to Digital Converters) may be required. Such components will be incorporated within the circuitry of the relevant sensors themselves.
Since our current assumption is that a full spectroscope will be needed, (requiring a USB port), we will be using a Raspberry Pi over the easier to use arduino architecture. If we subsequently determine that a USB port is not required, stepping down to a simpler Arduino should be a simple, and will reduce project complexity.

<table>
<thead>
<tr>
<th>µController</th>
<th>Arduino</th>
<th>Raspberry Pi</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB ports</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Availability</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>A/D Converters</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Programming Language</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Average:</td>
<td>6.8</td>
<td>7.6</td>
</tr>
</tbody>
</table>
Raspberry Pi: Risks

- Our current design assumes a worst-case scenario, in terms of complexity, and our other design components will be scaled accordingly. Remaining risks include:
  - SS.RSK1: Complexity of Raspberry Pi environment causes delays in testing other components.
  - SS.RSK2: Reduced number of ADCs on Raspberry pi requires additional design modifications on other components.
EPS: Risk Matrix

![Risk Matrix Diagram](image-url)
Test/Prototyping Plan

Alexsis Hundley-Kennaday
Lipo batteries are a hazard at NASA, but how do they cooperate with our hardware?

Risk/Concern

Verify battery longevity
Compare to Nickel Cadmium

Action

Receptiveness of mono & poly crystalline cells in rotation.

Test via shining visible light on cells rotating at 20Hz to verify voltage and current production.

Solar Cells

Receptiveness of resistors to quantify light intensity in rotation.

Test via shining visible light on photoresistors rotating at 20Hz to gauge response time.

Photoresistors

Power
Project Management Plan

Alexsis Hundley-Kennaday
Fall Term Schedule

Oct. 31
PDR Teleconference

Nov. 3
Prototyping supplies

ordered

Nov. 9-14
Construct prototypes

Nov. 14
Update

Teleconference (?)

Nov. 18
Conduct Prototype

tests

Nov. 19-27th
Refine goals

Dec. 2
Re-test if necessary

Dec. 5
CDR Teleconference

*One more meeting with WV to be held*

*All CSGC teleconferences held at 9:00am*
<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 9</td>
<td><em>Order Components:</em> Team members will determine the most critical components to be ordered to begin initial mechanical, electrical, and other advancements.</td>
</tr>
<tr>
<td>Jan. 9 - Feb.</td>
<td><em>Begin Subsystem Work:</em> Team members will begin the coding, construction, and testing of subsystems</td>
</tr>
<tr>
<td>Jan. 11</td>
<td><em>Final Selections made</em></td>
</tr>
<tr>
<td>Jan. 23</td>
<td><em>Update Teleconference:</em> Inform CSGC of any changes</td>
</tr>
<tr>
<td>Feb. 13</td>
<td><em>Subsystem Testing Review:</em> Inform CSGC of the operations in the subsystems.</td>
</tr>
<tr>
<td>Feb. 13</td>
<td><em>Second Payment Due</em></td>
</tr>
<tr>
<td>Feb. 24</td>
<td><em>Assemble Payload:</em> Ensure that all systems fit together and are primarily operational</td>
</tr>
<tr>
<td>Mar. 6</td>
<td><em>Update Teleconference:</em> Inform CSGC of any changes</td>
</tr>
<tr>
<td>Mar. 20</td>
<td><em>Integrate Systems:</em> Test that systems are operational and independent systems</td>
</tr>
<tr>
<td>Mar. 27</td>
<td><em>Integrated Subsystem Testing Review:</em> Inform CSGC of results in preliminary testing</td>
</tr>
<tr>
<td>Apr. 4</td>
<td><em>Final Payment Due</em></td>
</tr>
<tr>
<td>Apr. 10</td>
<td><em>Update Teleconference:</em> Inform CSGC of any changes</td>
</tr>
<tr>
<td>Apr. 24</td>
<td><em>Mission Simulation:</em> The payload will go through a final series of tests to ensure durability via spin tests and G-Force tests. In this segment of the testing, we will likely utilize the PSU drop tower to test for microgravity readings and equipment durability.</td>
</tr>
<tr>
<td>May. 22</td>
<td><em>Update Teleconference:</em> Inform CSGC of any changes</td>
</tr>
<tr>
<td>June. 1</td>
<td><em>Update Teleconference:</em> Inform CSGC of any changes</td>
</tr>
<tr>
<td>June. 5</td>
<td><em>Final Approvals:</em> The team will conduct a final weigh-in and confirm that the payload is flight ready. The team will then make the final shipment.</td>
</tr>
<tr>
<td>June. 14</td>
<td><em>Travel:</em> The team will begin their venture to the NASA Wallops Flight Facility.</td>
</tr>
</tbody>
</table>
## Overarching Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Single Costs</th>
<th>Multipliers</th>
<th>Actual Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload</td>
<td>$7000</td>
<td>1 payload</td>
<td>$7,000</td>
</tr>
<tr>
<td>Supplies</td>
<td>$5,000</td>
<td>1 set of supplies</td>
<td>$5,000</td>
</tr>
<tr>
<td>Plane Tickets</td>
<td>$700</td>
<td>4 people</td>
<td>$2,400</td>
</tr>
<tr>
<td>Room</td>
<td>$120 per night</td>
<td>2 rooms &amp; 9 nights</td>
<td>$2,160</td>
</tr>
<tr>
<td>Ground Transportation</td>
<td>$200 + Gas</td>
<td>1 Car + $200 in Gas</td>
<td>$400</td>
</tr>
<tr>
<td>20% Room for Error</td>
<td>$3,092</td>
<td>1 20% Margin</td>
<td>$3,392</td>
</tr>
</tbody>
</table>

**Total Costs** $20,352
**Parts Budget**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Quantity</th>
<th>Total Cost</th>
<th>Company</th>
<th>Part #</th>
<th>Dimensions</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrometer</td>
<td>3078</td>
<td>1</td>
<td>3078</td>
<td>Avantes</td>
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<tr>
<td>Solar Cells</td>
<td>2</td>
<td>8</td>
<td>16</td>
<td></td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motherboard PCB</td>
<td>100</td>
<td>2</td>
<td>200</td>
<td>Oregon Tech</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geiger PCB</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Power</td>
<td>1.49</td>
<td></td>
<td>0</td>
<td></td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activation (Snap Action Sw)</td>
<td>1.5</td>
<td>3</td>
<td>4.5</td>
<td>DigiKey</td>
<td>SW873-ND</td>
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<tr>
<td>Makrolon Plates</td>
<td>7.72</td>
<td>8</td>
<td>61.76</td>
<td>US Plastic Corp</td>
<td>43419</td>
<td>.220 x 12 x 12</td>
<td></td>
</tr>
<tr>
<td>Brackets</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Geiger Counter</td>
<td>149.95</td>
<td>2</td>
<td>299.9</td>
<td>SparkFun</td>
<td>(TBD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerometer</td>
<td>14.95</td>
<td>2</td>
<td>29.9</td>
<td>SparkFun</td>
<td>(Many options)</td>
<td></td>
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</tr>
<tr>
<td>Arduino ATMega 2560 R3</td>
<td>45.95</td>
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<td>99.9</td>
<td>SparkFun</td>
<td>DEV-11061</td>
<td></td>
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<tr>
<td>Arduino Uno R3</td>
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<td>24.95</td>
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<tr>
<td>SparkFun RedBoard (Prog)</td>
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<td>19.95</td>
<td>SparkFun</td>
<td>DEV-12757</td>
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<tr>
<td>SparkFun microSD Shield</td>
<td>14.95</td>
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<td>14.95</td>
<td>SparkFun</td>
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<td></td>
</tr>
<tr>
<td>Raspberry Pi 3</td>
<td>39.95</td>
<td>2</td>
<td>79.9</td>
<td>SparkFun</td>
<td>DEV-13825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raspberry Pi 2 - Model B (I)</td>
<td>49.95</td>
<td>0</td>
<td>0</td>
<td>SparkFun</td>
<td>DEV-13724</td>
<td></td>
<td></td>
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<tr>
<td>Mini Photocells</td>
<td>1.5</td>
<td>7</td>
<td>10.5</td>
<td>SparkFun</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 3780.46

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**Link**

- Quote sent by Con [http://www.futurlec.com](http://www.futurlec.com)
- [http://www.digikey.com](http://www.digikey.com)
- [http://www.usplastic.com](http://www.usplastic.com)
- [https://www.sparkfun.com](https://www.sparkfun.com)
# Team Contact Matrix

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role/Position</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>US?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexsis Hundley-Kennaday</td>
<td>Project Manager</td>
<td><a href="mailto:alexsis.kennaday@gmail.com">alexsis.kennaday@gmail.com</a></td>
<td>541-817-2995</td>
<td>Yes</td>
</tr>
<tr>
<td>Kevin Malstrom</td>
<td>Electrical Engr Lead</td>
<td><a href="mailto:kevin.malstrom@oit.edu">kevin.malstrom@oit.edu</a></td>
<td>503-320-9100</td>
<td>Yes</td>
</tr>
<tr>
<td>Mickie Cassady</td>
<td>Renewable Energy Engr</td>
<td><a href="mailto:mickie.cassady@oit.edu">mickie.cassady@oit.edu</a></td>
<td>503-547-7317</td>
<td>Yes</td>
</tr>
<tr>
<td>Eric Shaw-Stearns</td>
<td>Mechanical Engr Lead</td>
<td><a href="mailto:eric.shawstearns@oit.edu">eric.shawstearns@oit.edu</a></td>
<td>530-921-0299</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Each member has Dropbox access
No member changes since CoDR
### Team Availability Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
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**Green Indicates all 4 people**

**Yellow indicates 3 people**

No changes in time availability

Our term ends Dec. 9
Worries

• Accessibility of a spectroscope
  – No current budget for prototyping
  – Must conduct prototyping with photoresistors
• Solidworks to AutoCAD translation
  – Looking to purchase Solidworks with Veteran discount
Conclusion: Continuing forth

• Constructing our prototypes
• Prototyping at the Reed nuclear reactor
• Collaborating with WV for mechanical purposes
• Obtaining more leads for funding
• Overall, solidifying the project