Operation DUSTER

Debris Under Size 1cm Trajectory Edit for Removal Conceptual Design Review

Colorado School of Mines

Graham Braly, Meadow Bradsby, Kaylee Cuyler, Parker Damon, Forrest Doherty, Nik Geschwentner, Mark Gilliland, Brandon Hinkle, Ethan Howard, Bradley Jesteadt, Jason Mackay, Annie Strange, Claire Thomas, Brianne Treffner, and Taryn Tucker.

10/17/2019
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  – Mentors (Faculty, industry)
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• Section 4: Conclusions
Mission Overview

Brianne Treffner
Nik Geschwentner
Kaylee Cuyler
Mission Overview: Mission Statement

Space debris continues to be a growing problem as the barriers to entry decline every year. As more countries and private entities join the aerospace community there will be an increased probability of collisions in space. One we reach a critical mass of objects in orbit, there could be a cascade of collisions, hindering mankind’s access to the heavens for many years to come.

Project DUSTER will test 5 space debris remediation techniques to deorbit space debris less than 1 cm. Additionally, a demonstration communication system will be tested. The experimental results from this mission will be a proof of concept for the five debris removal techniques which, when combined with the communications system, will provide data that will allow for proof of concept of debris remediation in orbit.
Mission Overview: Mission Objectives

Payload

Debris Remediation Techniques
1. Cone Magnet
2. Static Charge
3. Laser

Proto Satellite Extras
4. Compressed Gas
5. Ballistics Gel
6. Communication System
   Camera Extension Boom
### Mission Overview: Mission Objectives

<table>
<thead>
<tr>
<th>Experiment Objective</th>
<th>Minimum Success Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Find the feasibility of using a cone-shaped magnet to alter debris trajectory...</td>
<td>• Particle trajectory altered by a magnet that is safe to mount on satellites.</td>
</tr>
<tr>
<td>02 Determine if a statically charged system can protect satellites from and/or...</td>
<td>• Particle trajectory altered under the force of static charge.</td>
</tr>
<tr>
<td>03 Determine the force or strength of laser needed to “move” or alter the trajectory of space debris.</td>
<td>• Particles moving under the force of the laser.</td>
</tr>
<tr>
<td>04 To verify if the force exerted by compressed gas is enough to move a particle...</td>
<td>• Particles moving under the force of the gas.</td>
</tr>
<tr>
<td>05 To determine if a form of ballistics gel would be a feasible solution to...</td>
<td>• Ballistic gel holding its molecular form in space.</td>
</tr>
<tr>
<td>06 Verify the communication system using ground based system.</td>
<td>• Reliable communication with the system after apogee.</td>
</tr>
</tbody>
</table>
Mission Overview: Theory and Concepts

As humanity continues to look to the stars as the last frontier, an increasing number of satellites, space stations, and other aerospace instruments have begun to clutter around Earth. While there are systems in place to track space debris and minimize collisions, there are millions of pieces of space debris too small to be tracked. These unknown particles can often cause the most serious damage.

According to a theory proposed by Donald Kessler in the 1970’s, there is a high risk of dangerous collisions occurring and causing a chain reaction resulting in more untrackable and unavoidable debris. This is known as Kessler syndrome and is one of the huge motivators for large-scale deorbiting of defunct satellites.
Mission Overview: Theory and Concepts

Micro-debris still poses a major threat to spacecraft, astronauts, and future missions. The risk of such missions would be greatly reduced if there was an efficient and low-cost way to deorbit the untrackable micro-debris. This debris travels at speeds up to 22,000 miles per hour, making collection or redirection very difficult. This is the main obstacle and focus of our mission.
Mission Overview: Expected Results

<table>
<thead>
<tr>
<th>Expect to Discover</th>
<th>Metric for Discovery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>01</strong> More deflection for particles near the point of the cone as opposed to those near the base.</td>
<td>● Deflection from path, by angle dependent on the magnetic susceptibility of the debris material.</td>
</tr>
<tr>
<td><strong>02</strong> Static source attracts and alters passing ‘debris’</td>
<td>● Mean particle trajectory/collision point shifts out of error of average initial particle trajectory.</td>
</tr>
<tr>
<td><strong>03</strong> A laser with a wavelength ~532 nm will be most efficient.</td>
<td>● The distance the debris travels in response to the laser.</td>
</tr>
<tr>
<td><strong>04</strong> The force of a compressed gas will be large enough to significantly move a particle in a vacuum.</td>
<td>● Deflection of the particle from its path should be more significant with increased pressure of gas.</td>
</tr>
<tr>
<td><strong>05</strong> We expect to discover that there is a gel that can hold its form and slow momentum of debris. The communication system using ground based system works as expected.</td>
<td>● Retainment of the gel in suborbital conditions &amp; the distance debris travels through the gel.</td>
</tr>
<tr>
<td><strong>06</strong></td>
<td>● Reliable communication with the system after apogee.</td>
</tr>
</tbody>
</table>
Mission Overview: Concept of Operations

1. Launch
2. Launch to Apogee
3. Apogee
4. Reentry
5. Chute Deploys
6. Splash Down
Mission Overview: Concept of Operations

**Apogee**

A. Cone Magnet: Particle launcher will begin launching 'debris' by the point of the cone.
   a. The camera will record video for each test. It will send small data samples for each particle launch during flight.
   b. At the end of the three minutes of apogee, the particle shooter will stop.

B. Static: For the first minute, data will be collected without static charge. This will develop base data.
   a. For the remainder of apogee, data will be collected similar to the cone magnet

C. Compressed Gas: Wooshing
   a. At apogee, the debris launching mechanism would release debris, and the compressed air "tank" would then release a set amount of pressurized gas.
   b. This gas would affect the particle in some way, which would be measured by a sensor to be determined.
Mission Overview: Concept of Operations

**Apogee**

D. Laser

a. At apogee the laser will shine on each debris piece for a preset amount of time.

b. The movement will then be measured with a lidar tracking device.
Design Overview

Bradley Jesteadt
Graham Braly
Brandon Hinkle
## Design Overview: Science Design

<table>
<thead>
<tr>
<th>Instrumentation/ Sensors/Devices</th>
<th>How will Science hardware achieve the mission?</th>
</tr>
</thead>
<tbody>
<tr>
<td>.5” cone magnet, camera, particle launcher.</td>
<td>01  ● Particle launcher will launch particles by the point of the magnet. The deflection of the particle will be recorded by the camera.</td>
</tr>
<tr>
<td>Static charge buildup device, camera, particle launcher.</td>
<td>02  ● Particle launcher will launch particles by the static charge. The deflection of the particle will be recorded by the camera.</td>
</tr>
<tr>
<td>Laser, particle held by ‘tether’ system, tracking system (camera.)</td>
<td>03  ● The laser will move the debris and the distance moved will be recorded.</td>
</tr>
<tr>
<td>Particle launcher, sensor to detect motion of particles, timed release mechanism on canister.</td>
<td>04  ● After releasing the particles into the area of interest, the canister will release the compressed gas, and the sensor will monitor the effect on the particles.  ● The gel will be flown to analyze its ability to stay structurally intact in space conditions.</td>
</tr>
<tr>
<td>Ballistics gel, debris launcher.</td>
<td>05</td>
</tr>
</tbody>
</table>
Design Overview: Engineering Design

E&M Static Attraction & Cone Magnet

- The cone magnet will exploit a strong magnetic field that will be used to alter the trajectory of debris. To not damage data collection, this cone will be mounted away from sensitive equipment.
- For the static charge test, the static shell will similarly be mounted away from sensitive equipment.
- Debris launched from particle shooter directly perpendicular to cone tip/static object to maximize effectiveness.
- Camera will be timed with particle shooters to take images of each trials results to transmit in-flight.
- Video of particle motion will be stored on the rocket for inspection upon landing and retrieval.

Laser

- When apogee is achieved, the release sensor will trigger and the debris will be free to drift through the capsule. The debris container doors will be flush to the sides of the capsule in order to minimize interference with the experiment.
- The laser will begin firing upon the small scale debris, pushing it to the far side of the capsule.
- Video will be stored on a SD card on the rocket for inspection upon landing and retrieval.
Design Overview: Engineering Design

Compressed Gas
- Compressed gas exerts a controlled force on a debris particle released at apogee
- Radar system will be used
- Data stored in an onboard flash drive
- LIDAR assesses change in momentum

Ballistic Gel
- Pressurized gas pushes this piece forward and some of the gas is released in order to launch the debris
- Power to rotate two servos required
- Debris launched at gel
- Light sensor used for measurement of impact
- Data from sensor stored

Communication System
- A simulated satellite will be used at apogee and communication to our ground-based system will be tested.

Camera Boom Extension
- A camera on a boom extension will be activated at apogee and after the rocket is fully despun and it will take a picture of the rocket with Earth behind.
Design Overview: Block Diagram

Rocket Power & Telemetry

Telemetry (type TBD)

Power <28 V

Video Storage Data Lines

Onboard Video Storage

1. Cone Magnet

2. Static Charge

3. Laser

4. Compressed Gas

5. Ballistics Gel

Power (voltage TBD)

Ground Communication Test

Onboard Battery

Legend

Internal Storage

Experiment Subsystem

Telemetry/Communication

CoDR 2019
Design Overview: Software Functional Block Diagram

Still Pretty High Level, Could Also Compartmentalize each experiment with multiple controllers for redundancy
Design Overview: Payload Layout
Design Overview: Payload Layout

Static Charge Sketch

Van De Graaff Shell

Compressed Gas Sketch

Particle Emitter
Design Overview: Payload Layout

**Laser Sketch**

- Top View
- Side View
- Front View
- Release Sensor
- Doors

**Ballistic Gel Sketch**

- Before "Fired"
- After "Fired"

*When time for experiment to begin, release sensor is triggered and releases debris by opening doors.*
Experiment Goals

- Take Pictures of Rocket and Earth
- Test Possible Extendable Boom Systems
  - Inflatable
  - Extendable like a tape measure
  - Foldable
  - Collapsible
- Look really cool
- Take really cool pictures
- Build an Aerospace Grade Selfie Stick
Management

Brianne Treffner
Mark Gilliland
Team Schedule

Fall 2019

August
- 19th: Classes start.
- 23rd: All team meeting.
- 29th: Project expo for Capstone students.

September
- 26th: Familiarize with research and work completed thus far.

October
- 10th: Rapid Prototypes Complete.
- 11th: Gold Mine fundraising materials due.
- 15th: PDR slides complete.
- 24th: Detailed CAD models.
- 28th: Launch party for Gold Mine.

November
- 7th: Subsystem build complete, begin testing.
- 21st: Testing complete, modifications to subsystems begin.
- 25th: CDR reviews complete.

December
- 5th: Second round of subsystem testing and modifications begins.
- 19th: All subsystems ready for integration.
- Break for Holiday.

Spring

1st Half of Semester
- Integrate subsystems and conduct testing.
- Begin writing paper.
- Work on debris simulations.

2nd Half of Semester
- Perform environmental testing on payload.
- Attend symposium.

Official RockSat-X Schedule Events
- Final Down Select & Flights Awarded
- 1st Payment Installment Due
- STR (Subsystems Testing Review)
- Experimental Decks and Connectors Sent
- ISTR (Integrated Subsystems Testing Review)
- Final Installment Due
- FMSR (Full Mission Simulation Review)
- IRR (Integration Readiness Review)

Official RockSat-X Schedule Events
- CoDR (Conceptual Design Review)
- Earnest Deposit ($2,000) Due
- PDR (Preliminary Design Review)

Official RockSat-X Schedule Events
- Initial Forms Due
- Initial Down Selections Made & Welcome Letters Sent
- Critical Design Review

Official RockSat-X Schedule Events
- PDR (Preliminary Design Review)
- CDR (Critical Design Review)
- Initial Forms Due
- Initial Down Selections Made & Welcome Letters Sent

Official RockSat-X Schedule Events
- CDR (Conceptual Design Review)
- Earnest Deposit ($2,000) Due
Team Organization

Colorado School of Mines 2019-2020 RockSat-X Team

Capstone Students
- Nik Geschwentner
- Kaylee Cuyler
- Mark Gilliland
- Bradley Jesteadt
- Brandon Hinkle
- Graham Braly

Extra-curricular Students
- Taryn Tucker
- Jason Mackay
- Claire Thomas
- Ethan Howard
- Annie Strange
- Forrest Doherty
- Meadow Bradsby
# Budget/ Purchase List

## Mines 2019-2020 RockSat-X Budget

<table>
<thead>
<tr>
<th>Payload Parts</th>
<th>Total</th>
<th>Estimated</th>
<th>Remaining</th>
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<tbody>
<tr>
<td>General</td>
<td>$70</td>
<td></td>
<td></td>
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<tr>
<td>StaticEM</td>
<td>$25</td>
<td></td>
<td></td>
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<tr>
<td>ConeEM</td>
<td>$116</td>
<td></td>
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<tr>
<td>CameraBoom</td>
<td>$575</td>
<td></td>
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<tr>
<td>Debris Launcher</td>
<td>$158</td>
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<td></td>
</tr>
<tr>
<td>Laser</td>
<td>$213</td>
<td></td>
<td></td>
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<tr>
<td>Communication</td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipping/Etc.</td>
<td>$75</td>
<td></td>
<td></td>
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<tr>
<td>Launch Fee</td>
<td>$14,000</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td>$15,232</td>
<td><strong>$4,000</strong></td>
<td><strong>$2,768</strong></td>
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<table>
<thead>
<tr>
<th>Travel</th>
<th>Per Person</th>
<th>Number of People</th>
<th>Total</th>
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<tr>
<td>June Airfare</td>
<td>$600</td>
<td>4</td>
<td>$2,400</td>
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<tr>
<td>June Accomodations</td>
<td>$150</td>
<td>4</td>
<td>$600</td>
</tr>
<tr>
<td>June Food</td>
<td>$0</td>
<td>4</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$4,000</strong></td>
<td></td>
<td><strong>$2,768</strong></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$35,007</strong></td>
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*THIS DOES NOT INCLUDE PER DIEMS*
Team Advisors

There are two primary team advisors:

1. CSM Space Grant Advisor
   Angel Abbud-Madrid
   aabbudma@mines.edu

2. Senior Design Capstone Advisor
   Jim Beseda
   jbeseda@mines.edu
# Team Contact Matrix

## Fall 2018 RS-X Contact Matrix

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Day Phone</th>
<th>Cell Phone</th>
<th>Receive Texts?</th>
<th>Email</th>
<th>Citizenship</th>
<th>Add to mailing list?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Brianne Treffner</td>
<td>303-249-2683</td>
<td>303-249-2683</td>
<td>Yes</td>
<td><a href="mailto:bri.treffner@mines.edu">bri.treffner@mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Annie Strange</td>
<td>720-690-3875</td>
<td>720-690-3875</td>
<td>Yes</td>
<td><a href="mailto:astrange@mymail.mines.edu">astrange@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>S.D. Member</td>
<td>Bradley Jesteadt</td>
<td>303-475-1474</td>
<td>303-475-1474</td>
<td>Yes</td>
<td><a href="mailto:bjjesteadt@mymail.mines.edu">bjjesteadt@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>S.D. Member</td>
<td>Brandon Hinkle</td>
<td>720-810-5159</td>
<td>720-810-5159</td>
<td>Yes</td>
<td><a href="mailto:bhinkle@mines.edu">bhinkle@mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Claire Thomas</td>
<td>346-270-5926</td>
<td>346-270-5926</td>
<td>Yes</td>
<td><a href="mailto:clairethomas@mymail.mines.edu">clairethomas@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Ethan Howard</td>
<td>916-517-8456</td>
<td>916-517-8456</td>
<td>Yes</td>
<td><a href="mailto:ethanhoward@mymail.mines.edu">ethanhoward@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Member</td>
<td>Forrest Doherty</td>
<td>970-319-3633</td>
<td>970-319-3633</td>
<td>Yes</td>
<td><a href="mailto:fdoherty@mymail.mines.edu">fdoherty@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>S.D. Member</td>
<td>Graham Braly</td>
<td>916-390-0010</td>
<td>916-390-0010</td>
<td>Yes</td>
<td><a href="mailto:gbraly@mymail.mines.edu">gbraly@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Jason Mackay</td>
<td>719-373-0148</td>
<td>719-373-0148</td>
<td>Yes</td>
<td><a href="mailto:jasonmackay@mymail.mines.edu">jasonmackay@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>S.D. Member</td>
<td>Kaylee Cuylner</td>
<td>505-340-6673</td>
<td>505-340-6673</td>
<td>Yes</td>
<td><a href="mailto:kcuylner@mines.edu">kcuylner@mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>S.D. Member</td>
<td>Mark Gilliland</td>
<td>720-331-7339</td>
<td>720-331-7339</td>
<td>Yes</td>
<td><a href="mailto:mgilliland@mymail.mines.edu">mgilliland@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Meadow Bradsby</td>
<td>303-974-0452</td>
<td>303-974-0452</td>
<td>Yes</td>
<td><a href="mailto:mbardsby@mymail.mines.edu">mbardsby@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>S.D. Member</td>
<td>Nik Geschwenter</td>
<td>303-506-2163</td>
<td>303-506-2163</td>
<td>Yes</td>
<td><a href="mailto:ngeschwenter@mymail.mines.edu">ngeschwenter@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Parker Damon</td>
<td>435-659-7781</td>
<td>435-659-7781</td>
<td>Yes</td>
<td><a href="mailto:pdamon@mines.edu">pdamon@mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Member</td>
<td>Taryn Tucker</td>
<td>719-641-3231</td>
<td>719-641-3231</td>
<td>Yes</td>
<td><a href="mailto:Taryntucker@mymail.mines.edu">Taryntucker@mymail.mines.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
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</table>
# Team Availability Matrix

## Colorado School of Mines

### Fall RS-X Team Availability Matrix

<table>
<thead>
<tr>
<th>PLEASE USE MOUNTAIN TIME ZONE TIMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>7:00 AM</td>
</tr>
<tr>
<td>8:00 AM</td>
</tr>
<tr>
<td>9:00 AM</td>
</tr>
<tr>
<td>10:00 AM</td>
</tr>
<tr>
<td>11:00 AM</td>
</tr>
<tr>
<td>12:00 PM</td>
</tr>
<tr>
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</tr>
<tr>
<td>2:00 PM</td>
</tr>
<tr>
<td>3:00 PM</td>
</tr>
<tr>
<td>4:00 PM</td>
</tr>
<tr>
<td>5:00 PM</td>
</tr>
<tr>
<td>Requirement</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Center of gravity in 1&quot; plane of plate?</td>
</tr>
<tr>
<td>Weight 30.0 +/- 1.0 (15.0 +/- 0.5) lbs?</td>
</tr>
<tr>
<td>Max Height &lt; 10.75&quot; (5.13&quot;)</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
</tr>
<tr>
<td>Using X GSE Line(s)</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
</tr>
<tr>
<td>Using &lt; 1 Ah</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
</tr>
<tr>
<td>Using deployable?</td>
</tr>
<tr>
<td>Whole team consists of US Persons</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
</tr>
</tbody>
</table>
Risks/Worries

- Momentum transfer affecting different experiments.
- Outgassing articles of the ballistics gel substance in the vacuum.
  - Vacuum chamber testing to follow with analysis of outgassing spectrum.
- Power consumption of Van de Graaff Machine and electronics in general.
  - More detail power analysis to follow.
- Waterproofing the electronics for splashdown.
- Manufacturing custom small debris launchers.
Conclusion

Space debris and its remediation is a unique and urgent issue that must be tackled. We propose many different experiments to test altering the trajectory of space debris to find a solution that is feasible and effective. Humankind hasn’t had to clean up trash travelling at 22,000 mph before. These unmet obstacles are going to need new and innovative techniques to solve them.
Next Steps

Our next goal as a team is to get the Preliminary Design Review (PDR) underway. In order to complete this we must complete the following.

- Refine and solidify scientific concepts.
  - Make final decisions as to what sensors work most efficiently.
- Construct a cohesive power layout for our design.
- Design a budget for the overall project.
  - As a team we must also discuss how we will achieve said budget.
- Consolidate our mission statement and goals for the mission.
  - Break down these statements into the 3 mission objectives.
- Verify subsystem design and depict the timing and connections of all subsystems (with respect to one another) for the duration of flight.

Further investigation:

- Overall goal of the ballistics gel experiment.
- Sensor needs and capabilities for use in several experiments.
- Debris launching mechanisms.