Project Helios

Preliminary Design Review

Capitol Technology University
11/15/2018
PDR Presentation Content

- **Section 1: Mission Overview**
  - Mission Statement
  - Mission Objectives
  - Theory and Concepts
  - Concept of Operations
  - Expected Results
  - Success Criteria
  - Top Level Requirements
  - De-Scopes and Off-Ramps

- **Section 2: Design Overview**
  - Engineering Design Overview
  - Functional Block Diagram
  - Payload Layout (sketches)
  - RockSat-X User’s Guide Compliance
  - Special Requests from Wallops
PDR Presentation Content

- Section 3: Subsystem Design
  - Structures
  - Mission Objectives
  - Command and Data Handling
  - Software
  - Other

- Section 4: Risk Matrices

- Section 5: Initial Test Plan
PDR Presentation Content

• Section 6: Management
  – Team Organization
  – Schedule
  – Budget
  – Mentors (Faculty, industry)
  – Status of Deposit
  – Risks/Concerns
  – Contact and Availability Matrices
  – Conclusion
Heritage

2018 Project Janus:
● Two independent payloads mimicked a satellite constellation.
● Primary CubeSat: laser distancing system to measure and record the average distance of the second CubeSat.
● Secondary CubeSat: moved a servo motor and a flag to trick the laser system.
● Integrated system with internal power and a single switch circuit with an Iridium Network.

2017 Project Hermes:
● Survivability test for the Iridium SBD modem at high velocities in the vacuum of space.
● Tested COTS equipment that interlinks with Iridium Satellites for more cost effective communications and to receive telemetry from the Iridium 9603 SBD modem.
● COTS gear was integrated into a simple in-house circuit with a battery pack powering the Raspberry PI, the UMCP team’s equipment, and Iridium modem.
● A special mount construction to support and boost the external Iridium antenna.
Mission Overview
Mission Overview: Theory and Concepts

- This year CTU has three projects:
  - Testing supercapacitors as a “battery backup”.
  - Proving, testing, and reacting to satellite vulnerabilities from the ground and other systems.
  - A Senior Project involving satellite communications that builds upon the Iridium satellite communications concepts previously flown by CTU in 2015, 2017, and 2018.
Mission Overview: Mission Statement

- The purpose of our flight is to demonstrate the use of supercapacitors as a practical battery backup and to possibly charge other internal batteries.
- Demonstrate the idea of deployable solar panels as a way to test the quick charging capabilities of a super capacitor.
- Demonstrate that even short flight systems can still be insecure. This will be proven by having remote access to the system from the ground and sending commands from the payload back to the ground once access is gained.
Mission Overview: Mission Objectives

- For the cyber exploit team, our goal is to gain access to the satellite through an unsecure data transfer. This experiment will prove that some satellites are not secured correctly. These transfers can be taken advantage of, and it is our mission to emphasize that no matter how small the project is, the data should be secure.
- The goal of the supercapacitors portion is to measure charging and discharging to gauge their effectiveness as a backup battery, and to record any detrimental effects of space on the supercapacitors.
- The goal of the solar panels is to show that moving parts in space is possible, as well as to see how well the solar power charges the capacitors.
- Give students experience with working as a team to accomplish a mission, as well as work with students with learning disabilities to give them the same opportunities.
**ConOps**

- **t = 0 min**
  - Altitude: 52km
  - End of Malemute burn

- **t = 0.6 min**
  - Altitude: 75km
  - Deploy Panels
  - Turn on Iridium modem & HAM Radio

- **t = 1.7 min**
  - Altitude: 95km
  - Panels Retract

- **t = 1.3 min**
  - Altitude: 95km
  - Launch
  - Computer boots

- **t = 3.1 min**
  - Altitude: ~150km
  - Data Collection

- **t = 4.0 min**
  - Altitude: 95km
  - Systems on

- **t = 4.5 min**
  - Altitude: 75km
  - Receiving data through Iridium

- **t = 7.5 min**
  - Chute Deploys

- **t = 15 min**
  - Splashdown
Mission Overview: Expected Results

- It is expected that our project will receive electrical data via Iridium from the supercapacitors (charging and discharging) to see how well they are holding charge.
- It is also expected that the solar panels will be able to deploy properly and provide a measurable amount of power to the satellite.
- Finally, the exploit team is expected to be able to intercept the unsecure signal and send basic commands to the satellite (such as a message saying “you’ve been compromised!”).
- The Senior Project is aimed to providing Iridium-based communication for part of our payload.
Mission Overview: Success Criteria

● Minimum Success Criteria
  ○ The minimum amount of data would be …..
    ■ “I’m alive” confirmation signal from payload

● Comprehensive Success Criteria
  ○ The ideal amount of data is …..
    ■ Controlled charge and discharge of supercapacitors to provide power to a subsystem within the payload
    ■ Success on the part of the exploitation team in intercepting and sending command signals to the payload
## Mission Overview: Top Level Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The deployable solar array shall deploy a full 90 degrees and the full height in less than 60 seconds.</td>
<td>Demonstration and Analysis</td>
<td>The array will be expanded to full length in upright position to confirm it does not exceed 90 degrees.</td>
</tr>
<tr>
<td>The system shall fit on a single RockSat-X deck.*</td>
<td>Inspection</td>
<td>Visual inspection will verify this requirement.</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-X Program.</td>
<td>Test</td>
<td>The system will be subjected to these vibration loads in June during test week.</td>
</tr>
</tbody>
</table>
Mission Overview: De-Scopes and Off-Ramps

If we do not get approval for the Iridium communications systems frequency of 1626.5 Mhz, or Ham frequency, or a scope that is still applicable to our project, we will scrap the remote exploitation aspect of our payload, or harden the payload to increase recovery likelihood.

If a suitable mechanism cannot be found to deploy the solar panels, we will rigidly surface mount the panels, upscaling them if needed to counter losses due to angling.

Budgeting constraints could require us to redesign or scale back our experiment.
Design Overview
System Overview: Mechanical Design

- The solar panels will deploy and provide power to the satellite auxiliary systems and charge the supercapacitor test circuits.
- The exploitation team will use an antenna or radio to communicate with the ground. The signal will be intercepted and used to send commands.
System Overview: Mechanical Design

- 1 NanoPi M4
- 1 Raspberry Pi 3+
- 1 HAM packet radio transmitter and packet radio receiver or other kind of radio
- 2 radio antennas
- Constructed of ¼ inch 60621 Aluminum
- The CubeSat will have two arms that move out that have solar panels on them to provide power
- Iridium modems and antennas
- Arduino
- Super Capacitors
- Voltage Regulator and relay
- On board battery/load
System Overview: Functional Block Diagram

Communication Lines

Exploitation Flowchart

- Raspberry Pi 3 (Compromised System)
- NanoPi M4
- HAM Radio
- Senior Project
- EspressoBox
- The Network Switch of the Payload
- Ground Team Attacking
- Ground Team Defending
- Indium
- Email Server
System Overview: Electrical Design
Electrical Design: Impulse-On Circuit
Electrical Design: Supercapacitors
System Overview: Payload interior Layout
System Overview: Payload Exterior
### RockSat-X User’s Guide Compliance

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1” plane of plate?</td>
<td>YES</td>
</tr>
<tr>
<td>Weight 30.0+/- 1.0 (15.0 +/- 0.5) lbs?</td>
<td>15.0 lbs</td>
</tr>
<tr>
<td>Max Height &lt; 10.75” (5.13”)</td>
<td>4”</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>YES</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
<td>NO</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>N/A</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
<td>N/A</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
<td>N/A</td>
</tr>
<tr>
<td>Using X GSE Line(s)</td>
<td>N/A</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
<td>N/A</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
<td>YES, TE-RA and TE-RB</td>
</tr>
<tr>
<td>Using &lt; 1 Ah (&lt; 0.5 Ah for half payload)</td>
<td>YES</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>YES</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>YES 1616-1626.5 MHz, 15W Max Transmit</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>YES</td>
</tr>
<tr>
<td>Whole team consists of US Persons</td>
<td>YES</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
<td>NO</td>
</tr>
</tbody>
</table>
System Overview: Special Requests

- The CubeSat is using Iridium communication systems so the antennas need to be zenith pointed.
- The solar panels need to be facing the sun unless we use motors to turn them to face the sun.
- The HAM Radio Antennas need to be facing the ground.
Subsystem Design
Subsystem Design: Structures

- Weight: 15lb
- 15W max power draw for communications
- Using a stepper motor for deploying the solar panels.
- Hinges for connecting the solar panels on the outside.
Subsystem Design: Power

The main power supply we will be using will be lithium ion batteries. The batteries will turn on when an impulse from the rocket closes a latching relay.

Currently the 10Ah Aiope external battery pack is our first choice. With two 5V 3.1A outputs this battery pack should cover our systems needs.

Additionally we will have Supercapacitors onboard that we will charge and use as a battery backup. These will charge off of the solar panel and at a specified point the battery will turn off to a pi zero and our supercapacitors will take over powering the pi for as long as they can.

The supercapacitors we are using are the 5V 5F AVX supercapacitors, pn: SCMT22C505PRBA0.
Subsystem Design: Command and Data Handling

- Electronics data is collected through Arduino sensors.
- Data is sent serially to the Raspberry Pi for compilation and transmission.
- The Raspberry Pi utilizes an Iridium Modem to transmit the data.
Subsystem Design: Software

- Languages
  - Python 3
  - C++
Systems Design: Backend Server

- We will be using Linux to run our backend server that will receive emails sent through Iridium.
- This server will be one of the targets the exploitation team.
Risk Matrices
## Risk Matrix: Structure

<table>
<thead>
<tr>
<th>Possibility</th>
<th>STR.RSK.1</th>
<th>STR.RSK.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Risk Matrix: Power

<table>
<thead>
<tr>
<th>Consequence</th>
<th>EE.RSK.1</th>
<th>EE.RSK.2</th>
<th>EE.RSK.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE.RSK.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE.RSK.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE.RSK.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **EE.RSK.1** - The batteries could not turn on due to complications arising from launch.
- **EE.RSK.2** - The supercapacitors could fail to charge.
- **EE.RSK.3** - The UPS system could lag or not pick up at all.
### Risk Matrix: Command and Data Handling

<table>
<thead>
<tr>
<th>Consequence</th>
<th>CaDH.RSK.1</th>
<th>CaDH.RSK.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Iridium modem registration failure.</td>
<td>Antenna Misalignment.</td>
</tr>
</tbody>
</table>

CaDH.RSK.1 - Iridium modem registration failure.
CaDH.RSK.2 - Antenna Misalignment.
### Risk Matrix: Programming

<table>
<thead>
<tr>
<th>Consequence</th>
<th>PRG.RSK.1 - Serial Port Misassignment.</th>
<th>PRG.RSK.2 - Measurement Device Malfunction</th>
<th>PRG.RSK.3 - Device Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possibility</td>
<td>Green</td>
<td>Yellow</td>
<td>Red</td>
</tr>
</tbody>
</table>

This matrix represents the risk assessment for programming-related risks, with each cell indicating the severity of the consequence and possibility of occurrence.
<table>
<thead>
<tr>
<th>Consequence</th>
<th>Possibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers won’t turn on so they can’t connect</td>
<td></td>
</tr>
<tr>
<td>Mailbox size</td>
<td>Can not transfer the data over the LAN</td>
</tr>
<tr>
<td>Connection issues</td>
<td>Can not connect to the HAM radio</td>
</tr>
<tr>
<td>Email size is too large</td>
<td>Emails sent get bounced back upon sending</td>
</tr>
<tr>
<td>Email size is too large</td>
<td>Scripts runs an error and can not find the host</td>
</tr>
<tr>
<td>Email size is too large</td>
<td></td>
</tr>
</tbody>
</table>
Initial Test Plan
Testing the payload before launch is a necessity. Our code is to run as intended on Raspberry Pis and Nano 3s. The Solar array is supposed to charge and power the supercapacitors. We will be testing different circuit designs to maximize circuit efficiency and effectiveness. System exploitation will be conducted during initial test runs, for analysis. This will allow us to be familiar with the system and how to breach the security of the cubeSAT. Lastly we need to test our payload to be waterproof. Recovery of the asset is essential. Construct prototype solar array, assure code works, make sure that it works as intended, test supercapacitors.
Management
Management: Team Organization

- Connor Schnitzer
  - Liaison
  - Electrical
    - Michael Rarick
      - Lead
    - Corey Price
    - Zachary Chavez
    - Gregory Patton
    - Keith Gorschboth
    - Melissa Burgos
  - Fabrication
    - Connor Schnitzer
      - Lead
    - Melissa Burgos
    - Keith Gorschboth
    - Anthony Winter
    - Christian Michael
    - Taylor Wright
    - Kim Frost
    - Zachary Chavez
  - Software
    - Edward Emmett
      - Lead
    - Gregory Patton
    - Taylor Wright
    - Sam Schatz
    - James Tribiano
    - Zach Shea
- Nate Zopfi
  - Team Manager
  - Software
    - Edward Emmett
      - Lead
    - Gregory Patton
    - Taylor Wright
    - Sam Schatz
    - James Tribiano
    - Zach Shea
    - Zachary Chavez
- Chris Murray
  - Communication
  - Exploitation
    - Sam Schatz
      - Lead
    - James Tribiano
    - Zach Shea
    - Keith Gorschboth
- CAD
  - Sam Schatz
    - Lead
  - Zachary Chavez
    - Connor Schnitzer
    - Keith Gorschboth
Management: 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>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Please use Mountain time zone times.

Example:

- Highest Priority: 1, 2, 3, 4
- Lowest Priority: 1, 1, 1, 1

Please place priority levels for times you are available. This is done by simply typing a 1, 2, 3, or 4 in each cell box.
## Contact Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Phone Num.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keith Gorschboth</td>
<td><a href="mailto:kagorschboth@captechu.edu">kagorschboth@captechu.edu</a></td>
<td>443-895-2019</td>
</tr>
<tr>
<td>Melissa Burgos</td>
<td><a href="mailto:melissaburgos@gmail.com">melissaburgos@gmail.com</a></td>
<td>443-955-8011</td>
</tr>
<tr>
<td>Kim Frost</td>
<td><a href="mailto:knfrost@captechu.edu">knfrost@captechu.edu</a></td>
<td>443-942-1420</td>
</tr>
<tr>
<td>Connor Schnitzer</td>
<td><a href="mailto:conman1029@gmail.com">conman1029@gmail.com</a></td>
<td>410-299-7641</td>
</tr>
<tr>
<td>Greg Patton</td>
<td><a href="mailto:gopatton@captechu.edu">gopatton@captechu.edu</a></td>
<td>240-753-4703</td>
</tr>
<tr>
<td>Corey Price</td>
<td><a href="mailto:coreyr97@gmail.com">coreyr97@gmail.com</a></td>
<td>302-864-5048</td>
</tr>
<tr>
<td>Christian Michael</td>
<td><a href="mailto:cdmichael@captechu.edu">cdmichael@captechu.edu</a></td>
<td>410-533-6444</td>
</tr>
<tr>
<td>Zachary Chavez</td>
<td><a href="mailto:zachchavezhoakt@gmail.com">zachchavezhoakt@gmail.com</a></td>
<td>215-429-6227</td>
</tr>
<tr>
<td>Brandon Gladden</td>
<td><a href="mailto:BAgladden@captechu.edu">BAgladden@captechu.edu</a></td>
<td>302-416-2301</td>
</tr>
<tr>
<td>James Tribiano</td>
<td><a href="mailto:james.tribiano@gmail.com">james.tribiano@gmail.com</a></td>
<td>347-884-0412</td>
</tr>
<tr>
<td>Logan Reardonz</td>
<td><a href="mailto:logan.reardanz@yahoo.com">logan.reardanz@yahoo.com</a></td>
<td>410-206-9307</td>
</tr>
<tr>
<td>Taylor Wright</td>
<td><a href="mailto:tawright@captechu.edu">tawright@captechu.edu</a></td>
<td>302-535-3851</td>
</tr>
<tr>
<td>Anthony Winter</td>
<td><a href="mailto:Winter.rebel@gmail.com">Winter.rebel@gmail.com</a></td>
<td>856-885-0491</td>
</tr>
<tr>
<td>Zach Shea</td>
<td><a href="mailto:zachshea98@gmail.com">zachshea98@gmail.com</a></td>
<td>615-448-8637</td>
</tr>
<tr>
<td>Edward Emmett</td>
<td><a href="mailto:ejemmett@captechu.edu">ejemmett@captechu.edu</a></td>
<td>302-430-4741</td>
</tr>
<tr>
<td>Michael Ranick</td>
<td><a href="mailto:mlarick13@gmail.com">mlarick13@gmail.com</a></td>
<td>301-512-8132</td>
</tr>
<tr>
<td>Nate Zopfi</td>
<td><a href="mailto:nazopfi@captechu.edu">nazopfi@captechu.edu</a></td>
<td>443-876-4569</td>
</tr>
</tbody>
</table>
Management: Schedule and Budget

- Team Helios meets every Thursday at 8pm (EDT), 6pm (GDT)
- Team meeting times are subject to change as necessary
- The preliminary budget is $2,500 for equipment and materials
- The deposit has been submitted in full.
Management: Mentors

- Professor Rishabh Maharaja – Helios Advisor/Concept Developer, RockSat-X 2018
- Tom Mellies - Helios Advisor
- Professor Walters - Helios Advisor
Management: Risks and Concerns

- Improper team communication.
- Loss of focus towards the mission objective.
- Members become unavailable or have to leave the project due to personal reasons/responsibilities.
Conclusion

This project will give students real life experience as engineers. Not only are we all working together to build the satellite, we are learning communication skills as well as relationship skills that will stick with us for the rest of our lives. The data we hope to gain from this experience will give the students working on the project a much greater insight into what their fields of study will consist of, as well as show them what it is like to work on a real engineering team. The students on team Helios are highly dedicated to working in these fields and will continue to show their dedication to the team throughout the entire process.
Possible Half Payload Design
Questions??
Our Questions

- Does half a payload mean half a plate or half the deck size (height)?
- Where in relation to the rocket will the sun be?