Critical Design Review

University of Hawai‘i Community Colleges

Honolulu, Windward, Kaua‘i

December 8, 2016
CDR Presentation Outline

• Section 1: Mission Overview
• Section 2: System Overview
• Section 3: Subsystem Design
• Section 4: Prototyping/Analysis
• Section 5: Manufacturing Plan
• Section 6: Testing Plan
• Section 7: User Guide Compliance
• Section 8: Project Management Plan (PMP)
1.0 Mission Overview
Mission Overview: Mission Purpose

Our participation in RockSat-X 2017 strategically supports the primary goals of Project Imua — namely:

- To encourage UHCC students to explore and enter STEM-based careers by engaging in team-oriented, problem-solving activities that emphasize the integration process involved in the design, fabrication, testing and documentation of launch-ready, space-bound payloads supporting scientific and/or engineering experiments.
- To establish and assess the feasibility of a permanent coalition of UHCC campuses for the collaborative development of payloads to be launched by the Hawai‘i Space Flight Lab and other launch facilities.
Mission Overview: Mission Statement

Payload Mission:

Our mission is to design a payload that supports two primary scientific and engineering experiments. The payload will also carry three secondary experiments.

1. Primary Experiments
   - Innovative sublimation rocket (WinCC)
   - Onboard, deck-mounted imagery cameras (HonCC)

2. Secondary Experiments
   - 9-axis motion tracking system (HonCC)
   - Hammerhead — a wireless lookback camera on ScubeR (KauCC)
   - Infrared Rangefinder for distance truthing (WinCC)
Mission Overview: Mission Objectives

Objective 1: Engage Students in STEM-based activities:
Provide UHCC students a challenging project-based mission in aerospace engineering that is adequately supported with scholarships and resources.

Objective 2: Demonstrate proof-of-concept and in-flight operation of primary and secondary experiments

1. Primary Experiments
   ○ Deploy sublimation rocket from payload bay near apogee.
   ○ Capture image of sublimation rocket’s release from CarRoLL.

2. Secondary Experiments
   ○ Evaluate 9-axis motion tracking device.
   ○ Take distance data of ScubeR using an infrared rangefinder.
   ○ Capture image of CarRoLL section after ScubeR release.
Mission Overview: Theory and Concepts (ScubeR) – Super Simple Sublimation Rocket

The simple concept of sublimation:

Sublimation is the result of a solid substance transitioning directly into a gas. This will occur when the surrounding temperature mildly increases and pressure radically decreases.

Sublimation Fueled Rocket:

A sublimating substance will act as fuel to thrust a rocket away from the payload bay near apogee.

Limited preliminary research has been conducted by Hawai‘i Space Flight Lab via the Hawai‘i Space Grant Consortium.

During last year’s flight, it was discovered that the rocket’s temperature did not vary appreciably from ambient temperatures, so a heating element will be included to increase the sublimation rate.
Theory and Concepts: Mobius Onboard Camera Systems

- Use pictured diameter of ScubeR body as it is released to determine its velocity.
Concept of Operations

Altitude

- **t ≈ 0 min**
  - Altitude: 17 km
  - Terrier ignition

- **t ≈ 2.0 min**
  - Altitude: 120 km
  - *ScubeR released*

- **t ≈ 1.7 min**
  - Altitude: 106 km
  - *ACS on target*

- **t ≈ 1.2 min**
  - Altitude: 75 km
  - *de-spin followed by clamshell separation*

- **Apogee**
  - **t ≈ 3.3 min**
  - Altitude: ≈ 151 km

- **Malemute burnout**
  - **t ≈ 0.52 min**
  - Altitude: 17 km

- **t ≈ 5.1 min**
  - Altitude: 98 km
  - *ACS spin up*

- **t ≈ 5.5 min**
  - Altitude: ≈ 66 km
  - *Power off to CarRoLL Shut off of onboard cameras*

- **t ≈ 7.6 min**
  - Altitude: 6 km
  - *Chute deploys*

- **t ≈ 15 min**
  - *Splash Down*
## Concept of Operations: Timer Events

We are requesting the use of one GSE line & one TE line.

<table>
<thead>
<tr>
<th>Event</th>
<th>Time On</th>
<th>Dwell</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE 1</td>
<td>T-180 sec</td>
<td>Duration of Flight</td>
<td>Supplies +5.0V power to Flight Computer (WinCC). Supplies +3.3V power to H-Bridge (WinCC).</td>
</tr>
<tr>
<td>GSE 2</td>
<td>T+000 sec</td>
<td>-</td>
<td>Not Used</td>
</tr>
<tr>
<td>TE-1</td>
<td>T+0.1 sec</td>
<td>Duration of Flight</td>
<td>Convert to +3.3V as signal to back-step and initiate stepper motor release of ScubeR from CarRoLL after de-spin and aft skirt deployment. (WinCC). Supplies +5.0V power to Onboard Camera (HonCC) and Rangefinder (WinCC).</td>
</tr>
<tr>
<td>TE-2</td>
<td>T+000 sec</td>
<td>-</td>
<td>Not Used</td>
</tr>
<tr>
<td>TE-3</td>
<td>T+000 sec</td>
<td>-</td>
<td>Not Used</td>
</tr>
<tr>
<td>TE-R</td>
<td>T+000 sec</td>
<td>-</td>
<td>Not Used</td>
</tr>
</tbody>
</table>
Expected Results (ScubeR)
Expected Results (ScubeR)

<table>
<thead>
<tr>
<th>Pressure (Pa)</th>
<th>Temp (K)</th>
<th>Altitude (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101.3k</td>
<td>300</td>
<td>Launch</td>
</tr>
<tr>
<td>28k</td>
<td>230</td>
<td>10</td>
</tr>
<tr>
<td>5.6k</td>
<td>210</td>
<td>20</td>
</tr>
<tr>
<td>1.3k</td>
<td>235</td>
<td>30</td>
</tr>
<tr>
<td>0.32k</td>
<td>260</td>
<td>40</td>
</tr>
<tr>
<td>0.1k</td>
<td>270</td>
<td>50</td>
</tr>
<tr>
<td>0.03k</td>
<td>260</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>210</td>
<td>70</td>
</tr>
<tr>
<td>1.3</td>
<td>190</td>
<td>80</td>
</tr>
<tr>
<td>0.25</td>
<td>210</td>
<td>90</td>
</tr>
<tr>
<td>0.056</td>
<td>240</td>
<td>100</td>
</tr>
<tr>
<td>0.016</td>
<td>270</td>
<td>110</td>
</tr>
<tr>
<td>0.005</td>
<td>330</td>
<td>120</td>
</tr>
<tr>
<td>0.002</td>
<td>390</td>
<td>130</td>
</tr>
</tbody>
</table>

Compressed Naphthalene
- Triple Point at 353 K and 1.059 kPa
- Expected to sublimate between 1.3 Pa and 0.25 Pa

ABS plastic rocket
- 3D printed

Expected Results (ScubeR)

ScubeR Thrust Estimates:

\[ T = \dot{m}v_e + P_{Vap}A_{th} = \dot{m}\sqrt{\frac{3k_BT}{M}} + P_{Vap}A_{th} \]

1. Vapor Pressure (8.64 Pa) alone: \( T=0.008 \, \text{N} \)

2. Thermodynamic Considerations:

\[ v_{rms} = \sqrt{\frac{3k_BT}{M}} \quad ; \quad v = v_{ex} \ln\left(\frac{M_{Total}}{M_{Total} - M_{fuel}}\right) \]

\[ I_{sp} = \frac{T}{W} = \frac{v_{ex}}{g} \]

Assuming a sublimation rate of 2 grams per second: \( T=0.05N \) the estimated ScubeR acceleration is 1.7 cm/s/s. A slower sublimation rate will result in a lower acceleration.

- Minimum depart velocity of \(~2.5\) cm/sec.
## Minimum Success Criteria: Primary Objectives

<table>
<thead>
<tr>
<th>Primary Objectives</th>
<th>Minimum success criteria:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage UHCC students in the design, fabrication and testing of a space-bound payload</td>
<td>5 scholarships awarded per semester; 5 students and 2 faculty mentors attend RockSat-X 2017’s test and launch events at WFF with a fully integrated, flight certified payload</td>
</tr>
<tr>
<td>Deploy sublimation rocket from payload bay near apogee</td>
<td>Achieve sublimation thrust sufficient for rocket to fully clear the CarRoLL</td>
</tr>
<tr>
<td>Image capture by onboard deck-mounted cameras</td>
<td>Record deployment of sublimation rocket with visual cues for determining its acceleration</td>
</tr>
</tbody>
</table>
## Minimum Success Criteria: Secondary Objectives

<table>
<thead>
<tr>
<th>Secondary Objectives</th>
<th>Minimum success criteria:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate operation of an 9-axis motion tracking device</td>
<td>Save orientation data to memory on deck plate</td>
</tr>
<tr>
<td>Take infrared ranging data of ScubeR</td>
<td>Record ranging data of ScubeR.</td>
</tr>
<tr>
<td>Image capture by lookback, rocket-mounted camera (Hammerhead)</td>
<td>Transmit and save images to memory on deck plate</td>
</tr>
</tbody>
</table>
### Desirable Success Criteria: Primary Objectives

<table>
<thead>
<tr>
<th>Primary Objectives</th>
<th>Desirable success criteria:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage UHCC students in the design, fabrication and testing of a space-bound payload.</td>
<td>10 scholarships awarded per semester; 8 students and 3 faculty mentors to attend RockSat-X 2017’s test and launch events at WFF with a fully integrated, flight certified payload.</td>
</tr>
<tr>
<td>Deploy sublimation rocket from payload bay near apogee.</td>
<td>Achieve sublimation thrust sufficient for rocket to fully clear the CarRoLL and with a greater than initial release velocity.</td>
</tr>
<tr>
<td>Image capture by onboard deck-mounted cameras (Mobius)</td>
<td>Record deployment of sublimation rocket with visual cues for determining its acceleration.</td>
</tr>
</tbody>
</table>
### Desirable Success Criteria: Secondary Objectives

<table>
<thead>
<tr>
<th>Secondary Objectives</th>
<th>Desirable success criteria:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate operation of an 9-axis motion tracking device</td>
<td>Save and recover orientation data to memory on deck plate</td>
</tr>
<tr>
<td>Take infrared ranging data of ScubeR</td>
<td>Record range data of ScubeR once per second</td>
</tr>
<tr>
<td>Image capture by lookback, rocket-mounted camera (Hammerhead)</td>
<td>Transmit and save images to memory on deck plate</td>
</tr>
</tbody>
</table>
**Top Level Requirements:**

Top system project level requirements and how they will be verified prior to flight.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScubeR</td>
<td><strong>Demonstration</strong></td>
<td>To release ScubeR at a minimum of 2.5 cm/s.</td>
</tr>
<tr>
<td>Onboard Camera</td>
<td><strong>Analysis</strong></td>
<td>Collect imagery of mock ScubeR launch to calculate acceleration</td>
</tr>
<tr>
<td>Flight Computer</td>
<td><strong>Inspection</strong></td>
<td>Records data from the Data Controller and records imagery from the lookback cameras.</td>
</tr>
<tr>
<td>Data Controller/Power Conditioning Board</td>
<td><strong>Test</strong></td>
<td>Verify power conditioning, data handling and storage.</td>
</tr>
<tr>
<td>Outboard Camera</td>
<td><strong>Test</strong></td>
<td>Verify outboard camera takes and uploads video via WiFi.</td>
</tr>
<tr>
<td>Infrared Rangefinder</td>
<td><strong>Analysis</strong></td>
<td>Collect infrared range data and calculate distance.</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSat-X program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
</tbody>
</table>
2.0 System Overview
Science Design: System Overview

Subsystems to Meet Overall Science Goals

- Sublimation Rocket (WinCC) - ScubeR
- Onboard Camera (HonCC) - Mobius Camera Modules
- Power Conditioning Board (WinCC)
- Flight Computer (WinCC) - Raspberry Pi 2
- Data Controller (HonCC) - Kolea05 - Metro Mini 328
- Lookback Dual Camera Module (KauCC) - Hammerhead
- Infrared Rangefinder (WinCC) - SF02/F laser rangefinder
Science Design Overview (ScubeR)

ScubeR utilizes the sublimation of Naphthalene in a zero-pressure environment directed through a de Laval nozzle to create a micro-thruster.
Heating Element

- We will be adding a heating element to ScubeR to increase the sublimation rate.
  - A length of Nickel Chromium wire approximately 8 cm long and 1 mm in diameter will be run in series with a 15-ohm resistor.
  - Power to heat the wire will be drawn from the internal battery of Hammerhead cameras.
Science Design Overview (Onboard Cameras)

\[ m = \frac{h_o}{h} = \text{Relative Magnification} = \frac{\text{Nozzle diameter at } x_o}{\text{Nozzle Diameter at } x} \]

\[ x = \frac{x_o}{m} = \frac{x_o h_o}{h} \]

\[ x = \frac{1}{2} (v_o + v)t \rightarrow v = \frac{2x}{t} - v_o \]

\[ v = \left[ \frac{2 \left( \frac{h_o}{h} \right) - 1}{t} \right] x_o = \left( \frac{x_o}{t} \right) \left[ 2m - \frac{t}{t_o} \right] \]

\[ \frac{\delta v}{v} = \sqrt{\left( \frac{\delta t}{t} \right)^2 + \left( \frac{\delta h}{h} \right)^2} \]

Imagery will be used to calculate the distance and velocity of ScubeR deployment using the apparent image height.
Science Design Overview (Onboard Cameras)

- Two onboard Mobius cameras will record imagery of ScubeR deployment.
  - Camera 1 will record time-lapse photos.
  - Camera 2 will record video.

- Data from each camera will be stored on SD cards on Mobius circuit boards.

- Cameras will be housed in a shielded container mounted on the base-plate.

- Imagery will be used to calculate the distance and velocity of ScubeR deployment.
System Overview: System Changes Since PDR

Mobius Onboard Cameras
We may add a larger box for the securement of the Mobius camera hardware.

Power Conditioning Board
We are adding a 5.0 DC-DC converter to the PCB in connection with the TE-1 line.

Data Controller
We are adding an analog accelerometer.

Telemetry
Move the Rangefinder assignment, adding 3 more analog lines to support an analog accelerometer.
System Overview: Mechanical Design

ScubeR and Lookback Assembly

ScubeR

Lookback Camera
System Overview: Mechanical Design-Angle view

- Holds Mobius Camera circuit boards
- Holds Power Conditioning Board
- Holds flight computer and data controller
System Overview: Mechanical Design - Top View

General Layout
System Overview: Electrical Design
Electrical Schematic: Onboard Cameras

Hammond Box housing Mobius Onboard Camera #1 and Camera #2 Circuit Boards
Electrical Schematic: Data Controller
System Overview: Timer Events and Software Design

**Power on GSE-1**
- Power to PCB
- Convert 32V to 5.0V
- Power to H-Bridge and Stepper motor
- Power on to flight computer
- Power on to Data Controller
- Begin backstep script for stepper motor

**Timer Event 1 TE-RA**
- Power to PCB
- Convert 32V to 5.0V
- Convert 32V to 3.3V
- Power on Mobius Cameras
- Store Video

**Power to PCB**
- Convert 32V to 5.0V
- Convert 32V to 3.3V
- Power on Laser Range finder
- Send and Save Range Data to Data Controller
- Initialize Stepper motor forward script
- Signal to RPi to begin dwell time of 120s
Project Imua Year 3 utilizes partnerships with:

- Hawai’i Space Grant Consortium (HSGC) for the funding of Project Imua.
- Hawai’i Space Flight Lab (HSFL) for vacuum testing of ScubeR reactant sublimation.
- NASA for deck space within their 2-stage suborbital sounding rocket.
De-Scopes and Off-Ramps

- Our payload has no de-scopes or off-ramps
System Overview: Special Requests

Our only special request for WFF is to have an orientation of the release of ScubeR along the eastern edge of the horizon.

46.014 Pointing Request

- View downwards from zenith to nadir (earth behind payload)

- Desire to have active ACS throughout flight. Hold on target.
3.0 Subsystem Design
Subsystem Design: System Overview

Major Subsystems

- **Sublimation Rocket (WinCC) - ScubeR**
  - 3D Printed
  - 25cm (estimated) by 4-cm diameter

- **Onboard Camera (HonCC) - Mobius Camera Modules**
  - Mass ~ 0.29 lbs
  - 25mm x 45mm x 60mm (possible to change)

- **Power Conditioning Board (WinCC)**
  - Step down voltage from 32V to 5V and 3.3V

- **Flight Computer (WinCC) - Raspberry Pi 2**
  - Store data from the Data Controller subsystem
  - Setup WiFi

- **Data Controller (HonCC) - Kolea05 - Metro Mini 328**
  - Collect data from a 9-axis motion detector, rangefinder and two accelerometers
  - Process to fit telemetry protocols and send it via asynchronous to ground and to Flight Computer
  - Inform Flight Computer that launch has occurred

- **Lookback Dual Camera Module (KauCC) - Hammerhead**
  - Capture pictures/video of CarRoLL and transmit them back to Flight Computer

- **Infrared Rangefinder (WinCC)**
  - SF11-C
  - 3cm x 5.65cm x 5cm

- **Heritage Elements**
  - Raspberry Pi

- **Major technology dependencies?**
  - No
Subsystem Design (ScubeR, Onboard & Outboard Cameras)
ScubeR is 3D printed with ABS plastic. The heating element is Ni-Chrome wire. It has a total weight of 1.7lb.

ScubeR consists of 5 parts:
1. Fuselage
2. de Laval Nozzle
3. Plug
4. Heating Element
5. Fuel: Naphthalene

Cale
Subsystem Design: Structure - Mechanical Interface (ScubeR)

Stepper Motor-On hand hardware

31564-MS
NEMA 17 STEPPER with LEADSCREW

- **P/N:** 42HD0403-100L
- **NEMA:** 17
- **COIL:** 1.5A/1.3 ohm
- **TYPE:** 2 Phase 4 Lead Bi-Polar or H Drive
  - 1.8 Degree stepper motor with a 8mm Dia./2mm Pitch 4 Start Helical leadscrew
  - 100mm steel long with brass traveler. 8mm/turn or .04mm/step.
  - 4 corner M3X 0.5 metric mounting holes. 13" leads.
- **SQ.** 1-5/8"  **L:** 1-3/8" (Body)  **WT:** 0.2 lbs

<table>
<thead>
<tr>
<th>P/N</th>
<th>Step Angle</th>
<th>phase V</th>
<th>phase I</th>
<th>phase Res.</th>
<th>phase Ind.</th>
<th>Inertia</th>
<th>Leads</th>
<th>WT.</th>
<th>Body L.</th>
<th>Shaft L.</th>
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<tbody>
<tr>
<td>42HD0403</td>
<td>1.8</td>
<td>1.95</td>
<td>1.5</td>
<td>1.3</td>
<td>1.5</td>
<td>2.2</td>
<td>4</td>
<td>0.2</td>
<td>33</td>
<td>100</td>
</tr>
</tbody>
</table>

MOTOR WINDING
Subsystem Design (ScubeR/Lookback Electrical Components)

Dual Camera Module

Overo COM

WiFi Signal

Limit Switch

Power +

Power -

Battery (may require 2 batteries)

USB Data

WiFi Receiver

Heating Element

Battery (may require 2 batteries)
# Subsystem Design (Lookback Camera WiFi)

**• USB to WiFi Module (Receiver connected to flight computer)**

<table>
<thead>
<tr>
<th>Model</th>
<th>Ralink RT3070</th>
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</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4GHz, ISM band</td>
</tr>
<tr>
<td>Standard</td>
<td>802.11b/g/n</td>
</tr>
<tr>
<td>Transmit Power: 802.11b</td>
<td>-84+/−1.5dBm@11Mbps</td>
</tr>
<tr>
<td>Transmit Power: 802.11g</td>
<td>-69+/−1.5dBm@54Mbps</td>
</tr>
<tr>
<td>Board size</td>
<td>40mm x 18mm</td>
</tr>
<tr>
<td>Weight</td>
<td>4.25g</td>
</tr>
</tbody>
</table>

**• Overo COM (Camera host and WiFi sender)**

<table>
<thead>
<tr>
<th>Model</th>
<th>Overo Firestorm-Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4GHz, ISM band</td>
</tr>
<tr>
<td>Standard</td>
<td>802.11a/b/g/n</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>17.3 dBm (@1 DSSS)</td>
</tr>
<tr>
<td>Board size</td>
<td>58mm x 18mm</td>
</tr>
</tbody>
</table>
## Subsystem Design (Lookback Camera)

### ELP Dual Lens USB Camera Module

<table>
<thead>
<tr>
<th>Model</th>
<th>ELP-1MP2CAM001-HOV90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Resolution</td>
<td>1280(H)X720(V)</td>
</tr>
<tr>
<td>Compression format</td>
<td>MJPEG / YUV2 (YUYV)</td>
</tr>
<tr>
<td>Resolution &amp; frame</td>
<td>1280X720 MJPEG@30fps YUY2@10fps 640X360MJPEG@60fps YUY2@30fps</td>
</tr>
<tr>
<td>Mini illumination</td>
<td>0.1 lux</td>
</tr>
<tr>
<td>Connecting Port type</td>
<td>USB2.0 High Speed</td>
</tr>
<tr>
<td>Lens Parameter</td>
<td>HOV 90 degree</td>
</tr>
<tr>
<td>Power supply</td>
<td>USB BUS POWER Micro USB</td>
</tr>
<tr>
<td>Power supply</td>
<td>DC5V</td>
</tr>
<tr>
<td>Working current</td>
<td>130mA~180mA</td>
</tr>
<tr>
<td>Working temperature</td>
<td>-20~85℃</td>
</tr>
<tr>
<td>Board size</td>
<td>75mm x 15mm</td>
</tr>
<tr>
<td>Lense height</td>
<td>14mm</td>
</tr>
<tr>
<td>Board weight</td>
<td>6.85g</td>
</tr>
</tbody>
</table>
Prototyping one of two Mobius camera systems outside of housing
Subsystem Design: Structure (Onboard Cameras)

Onboard Mobius camera circuit boards outside of housing
Camera 1 (time-lapse) and Camera 2 (video)
Lenses at right

Size: 25mm x 45mm x 60mm
Power: 450mA at 5V for each camera
Mass: 0.29 lbs
Subsystem Design: Structure (Onboard Cameras)

- Onboard Camera Housing-Hammond Box

**DESIGNED FOR 39MM WIDE PC BOARD**

Enclosures can be Factory Modified (Milling, Drilling, Printing etc.)
Contact Factory mm@hammondmg.com for quotes
Solid models of this enclosure available in STEP or IGES

**NOTE**
Purchased assembly includes box, plastic bezels, End Panels, Custom #8 Tight screws and self adhesive rubber feet
Box made from Extruded Aluminium 6063 T5
Bezels made with polycarbonate
End Plates made from 5052-H32 Aluminium

1455D601

PART NUMBERS

<table>
<thead>
<tr>
<th>Color</th>
<th>Code</th>
</tr>
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<tbody>
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<td>Clear Anodized</td>
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</tr>
<tr>
<td>Black Anodized</td>
<td>1455D01BU</td>
</tr>
<tr>
<td>Blue Anodized</td>
<td>1455D01BU</td>
</tr>
<tr>
<td>Red Anodized</td>
<td>1455D01RD</td>
</tr>
</tbody>
</table>

ACCESSORIES

See website for accessories

Hammond Manufacturing

1455D601

www.hammondmg.com
Kolea05 is the name of the data controller subsystem based on the Adafruit Metro Mini 328 controller which will do a measure, transmit and control mission in PrIMEAT.

- **Measure**
  - Acceleration in the X, Y and Z axis from 3 motion sensors
  - Gyroscope in the X, Y and Z axis from the IMU
  - Magnetometer in the X, Y, and Z axis from the IMU
  - Voltage levels from the Rangefinder subsystem

- **Transmit**
  - Data Stream #1 to the Flight Computer subsystem
  - Data Stream #2 to the rocket’s radio downlink

- **Control**
  - Digital signal to the Flight Computer subsystem when launch has occurred

- **Sensors in order of being polled by the controller**
  - #1 - LIS3DH digital accelerometer
  - #2 - ADXL326 analog accelerometer
  - #3 - L3GD20H (gyroscope) + LSM303 (accelerometer and magnetometer) digital IMU
  - #4 - Voltage from the Rangefinder subsystem
Subsystem Design: Structure (Data Controller)

Launch occurrence signal
To GPIO on flight computer

Sensor #4: Rangefinder

Sensor #2: Accelerometer #2

Controller

Stream #1: To flight computer

Stream #2: To rocket transmitter

I²C Bus

Sensor #1: Accelerometer #1

Sensor #3: IMU

Color codes:
- Analog
- Digital
- Serial
- I²C
**Subsystem Design: Structure (Data Controller)**

**Power** - Comes from the flight computer via USB cable. This supplies 5 volts to the controller. The controller also has a 5 volt regulator that will supply power to the rest of the subsystem.

**Size** - 165mm x 46mm x 30mm *(Unit 5)*

**Weight** - 102 grams *(Unit 5)*

---

**Left to right**

**Controller:** Metro Mini 328

**LED (above):** To simulate when launch has occurred

**Sensor #2:** ADXL326 accelerometer (analog)

**Sensor #1:** LIS3DH accelerometer (I²C)

**Sensor #3:** L3GD20H + LSM303 IMU (I²C)

**Sensor #4:** LM34 temperature sensor (analog - filling in for the Rangefinder)

**Jumper:** Simulates downlink to the rocket’s transmitter
Printed circuit board layout for the data controller subsystem.

This board is meant for ground testing.

Red lines are for the top layer.

Green lines are for the bottom layer.

Yellow lines are etched on the circuit board.
Subsystem Design: Structure (Flight Computer)

- Microcontroller: Raspberry Pi 2 model B
  - size: 85.5mm x 55mm X 15mm
  - weight: 45g (1.6 oz)
  - power: 5v from GSE-1 @ T= -180s
Subsystem Design: **Structure (Flight Computer)**

- **Flight Computer**: Receives 5V from GSE (@ T=-180s) via PCB
- **Stepper Motor**: Receives 3.3V during backstepping for a rough total of 8.64 sec from TE-1 @ T=+0.1s to T=+120s. At T=+120s the stepper motor steps forward continuously for 11 sec to deploy ScubeR.
Subsystem Design: Structure (Flight Computer)

- SM pin: B-1B
- SM pin: A-1B
- SM (Stepper Motor) pin: B-1A
- Launch Trigger Pin
- SM pin: A-1A

Raspberry Pi A+ / B+ and Raspberry Pi 2 GPIO pins:
- GPIO
- Ground
- 3.3v
- 5v
- EEPROM
  Advanced use only!
Subsystem Design: **Structure (Infrared Rangefinder)**

- Detector Model: SF02 Laser Infrared Rangefinder
- Detector Weight: **69g**
- Detector Power: **USB 5v**
- Detector Size: 27 x 59 x 86 mm

![Diagram showing the structure of the Infrared Rangefinder](image)
Mobius Camera_1:
- Embedded firmware enables stand-alone operation
- Operates in Video mode
- Captures and stores 5-min video clips of ScubeR release
- Data is stored locally to micro SD-card contained within camera PCB enclosure

Mobius Camera_2:
- Embedded firmware enables stand-alone operation
- Operates in Photo mode
- Captures and stores time-lapse photos of ScubeR release
- Data is stored locally to micro SD-card contained within camera PCB enclosure
Subsystem Design: Software (Flight Computer)

Power from GSE $T = -180s$ via PCB

Launch trigger from TE-1 via PCB

Main Thread

- Pre-Launch Wait Loop
- Backstepping Motor until $T = +120s$
- Run Stepper Motor Forwards for 11 sec to launch ScubeR

Backstep Loop

- Wait 0.928 sec
- Run Stepper Motor in Reverse for 0.072 sec

Serial Connection Thread

- Record Data from Data Controller via serial connection

Lookback Camera Thread

- Save Images from lookback cameras
Subsystem Design: **Software (Data Controller)**

- Power on via the Flight Computer
- Initialize counters and set up link to sensors
- Get elapsed time
- Get data from accelerometers, IMU and rangefinder
- Check for higher than usual acceleration.
- Send text data to flight computer and to Wallops
- Update counters, inform flight computer of launch
Subsystem Design: Software (Lookback Camera)

1. Power on at ScubeR launch
2. Create Wi-Fi link with Flight Computer upon bootup
3. Begin recording pictures/video
4. Transmit pic/vid data to Flight Computer via Wi-Fi link
5. Save pictures/video to Flight Computer SD card

Loop runs until power is lost or WiFi range is exceeded.
Subsystem Design: **Software (Rangeﬁnder)**

Terminal emulation program
1. ScubeR will not clear the CarRoLL before re-entry because of a delay in sublimation.
2. Stepper Motor might not work.
3. Images may become distorted if fog/outgassing gets on camera lens.
4. Camera may fail to capture images if the ribbon cable interface is damaged during launch.
5. Video images will not be stored if power to unit is removed before five-minutes from power on.
6. Testing the integrated subsystem will be delayed if the PCB board isn’t delivered on time.
7. Does not receive power or timer event from PCB.
8. Unable to record serial data from data controller.
9. Unable to record imagery from lookback camera.
10. Unable to communicate with H-bridge and run stepper motor.
11. Units undergoing test on model rockets might get lost during the flight. There might be delays in getting replacement parts.
12. After ScubeR launch, the relative orientation of the CarRoLL and ScubeR may change faster than expected, cutting short the time that the CarRoLL will be in view of the cameras.
13. The USB power may not work.
14. Too much processing may slow down the Raspberry Pi 2 to the point that it fails to initiate a controlled timing event.
15. Data Loss from re-entry.
1. ScubeR will not clear the CarRoLL before re-entry because of a delay in sublimation.
2. Stepper Motor might not work.
3. Images may become distorted if fog/outgassing gets on camera lens.
4. Camera may fail to capture images if the ribbon cable interface is damaged during launch.
5. Video images will not be stored if power to unit is removed before five-minutes from power on.
6. Testing the integrated subsystem will be delayed if the PCB board isn’t delivered on time.
7. Does not receive power or timer event from PCB.
8. Unable to record serial data from Data Controller.
9. Unable to record imagery from Lookback Camera.
10. Unable to communicate with H-bridge and run stepper motor.
11. Units undergoing test on model rockets might get lost during the flight. There might be delays in getting replacement parts.
12. After ScubeR launch, the relative orientation of the CarRoLL and ScubeR may change faster than expected, cutting short the time that the CarRoLL will be in view of the cameras.
13. The USB power may not work.
14. Too much processing may slow down the Raspberry Pi 2 to the point that it fails to initiate a controlled timing event.
15. Data Loss from re-entry.
Risk Matrix (Summary)

Consequence

Possibility

15
7,16
3,9,11
13,14

1
4,5,6,8,10
2
12

Damien
## Subsystem Design (Detailed Weight Budget)

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Weight (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Deck</td>
<td>3.425</td>
</tr>
<tr>
<td>ScubeR+Stepper Motor + Lookback</td>
<td>1.7</td>
</tr>
<tr>
<td>Onboard Camera Units (Camera boards, cabling, lens, lens housing)</td>
<td>0.29</td>
</tr>
<tr>
<td>Data controller</td>
<td>0.22</td>
</tr>
<tr>
<td>Powerboard/Telemetry (Flight computer)</td>
<td>0.176</td>
</tr>
<tr>
<td>Infrared Rangefinder</td>
<td>0.152</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5.963</strong></td>
</tr>
<tr>
<td><strong>Over/Under (15.0±0.5 lbf (6.8 kg))</strong></td>
<td><strong>9.037</strong></td>
</tr>
</tbody>
</table>
## Subsystem Design (Power Usage Table)

<table>
<thead>
<tr>
<th>Component</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power (W)</th>
<th>Conversion Efficiency (%)</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power (W)</th>
<th>Time On (min)</th>
<th>mAh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Computer and Data Controller</td>
<td>5.0</td>
<td>0.9</td>
<td>4.5</td>
<td>80.0</td>
<td>32.0</td>
<td>0.156</td>
<td>5.0</td>
<td>5.53</td>
<td>14.4</td>
</tr>
<tr>
<td>Stepper Motor</td>
<td>3.3</td>
<td>0.290</td>
<td>0.96</td>
<td>80.0</td>
<td>32.0</td>
<td>0.057</td>
<td>1.81</td>
<td>0.033</td>
<td>0.316</td>
</tr>
<tr>
<td>Onboard Camera (Mobius)</td>
<td>5.0</td>
<td>0.80</td>
<td>4.0</td>
<td>80.0</td>
<td>32.0</td>
<td>0.156</td>
<td>5.0</td>
<td>5.53</td>
<td>14.4</td>
</tr>
<tr>
<td>Lookback Cam*</td>
<td>5.0</td>
<td>0.070</td>
<td>0.35</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>3.00</td>
<td>n/a</td>
</tr>
<tr>
<td>New Infrared Rangefinder</td>
<td>5.0</td>
<td>0.200</td>
<td>1.00</td>
<td>80.0</td>
<td>32.0</td>
<td>0.039</td>
<td>1.25</td>
<td>5.53</td>
<td>3.59</td>
</tr>
</tbody>
</table>

*Lookback Camera is powered by internal battery.

<table>
<thead>
<tr>
<th>Total Battery Usage</th>
<th>Total Current (A)</th>
<th>Total Capacity (Ah)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiments</td>
<td>0.408 A</td>
<td>0.0327 Ah</td>
</tr>
</tbody>
</table>

---

**Total Battery Usage**

- **Experiments**: 0.408 A
- **Total Capacity**: 0.0327 Ah
4.0 Prototyping/Analysis Results/Plans
Test/Prototyping Plan (ScubeR)

- Establish connection between power and H-bridge
- Establish H-bridge to stepper motor connection
- Establish reverse thread script for stepper motor
- Calibrate stepper motor speed based on simulated tests
- Integrate with V-channel

- Test subassembly after integration with V-channel
- Deliver to system integrators
- Environmental Testing

Statuses:
- Complete
- In Progress
Test/Prototyping Plan (Onboard Cameras)

1. Establish link between power and camera system
2. Establish cameras turn on and collect imagery
3. Test cameras with simulated rocket release
4. Position camera based on simulations
5. Develop and test calculations for image processing
6. Integrate with aluminum housing
7. Test subassembly after integration with aluminum housing
8. Deliver to system integrators
9. Environmental Testing

Onkar

2017 CDR 75
Prototyping one of two camera systems (camera 1) mounted aft of ScubeR launch platform.

Size: 25mm x 45mm x 60mm  
Power: 450mA at 5V for each camera  
Mass: 0.29 lbs  
Mechanical/ electrical interfaces with other subsystems not yet tested.
### Test/Prototyping Plan (Mobius Onboard Camera Systems)

#### What has been tested:

The onboard camera system’s ability to power up from external power supply and interface board in open bench test. i.e. 5.0VDC @ ~0.87A (success).

Ability to capture and store still photos (every 2s) and videos (1 every 5min) to MicroSD card on camera circuit board. (success)

Programmed each camera to boot up and start recording in photo and video mode using GUI. (success)

The quality and resolution of photos and videos sufficient for acceleration calculations, but lacking real time clock time stamp, so timecode is relative only. (Partial success)
Test/Prototyping Plan (Power Conditioning Board)

Establish a connection between PCB and the rocket battery power

Verify power on of PCB

Verify TE-1 change 32V coming into PCB to 5V to the RPi 2 B

Verify TE-1 change 32V coming into the PCB to 3.3V signal going to the RPi 2 B flight computer

Verify GSE-1 change 32V coming into the PCB to 3.3V to the Mobius cameras

Verify GSE-1 change 32V coming into PCB to 3.3V to the H-bridge

Verify change 32V coming into the PCB to 3V to the Rangefinder

Test PCB after integration with aluminum housing

Deliver to system integrators

Environmental Testing

Cale
Establish link between power, H-bridge, lookback cameras and data controller

Test Step sequence for motor via H-Bridge

Allocate GPIO pins for 3.3V signal from TE-1

Test image recording and serial data recording

Calculate timing and construct flight event sequence

Integrate with aluminum housing

Test subassembly after integration with aluminum housing

Deliver to system integrators

Environmental Testing

Deliver to system integrators

Environmental Testing
Test Event Logging:
Project Imua 3
date = Mon Nov  7 23:50:10 2016
time_init = 1478598610.94

[0.059681892395, 0.059681892395][M: 0]: Start prelaunch loop
[4.66145300865, 4.66145300865][M: 1]: End prelaunch loop
[4.66369795799, 2.00271606445e-05][M: 2]: Received Launch Trigger.
[4.66662192345, 0.00294399261475][M: 3]: Start backstep loop
[5.6666238308, 1.00294589996][M: 4]: Backstep
[6.6666238308, 2.00294589996][M: 5]: Backstep
[7.66662597656, 3.00294804573][M: 6]: Backstep
[8.66662597656, 4.00294804573][M: 7]: Backstep
[9.66662693024, 5.0029489994][M: 8]: Backstep
[10.6666300297, 6.00295209885][M: 9]: Backstep
[11.6666328907, 7.00295495987][M: 10]: Backstep
[12.6666350365, 8.00295710564][M: 11]: Backstep
[13.6666409969, 9.0029630661][M: 12]: Backstep
[14.6666228771, 10.0029449463][M: 13]: End backstep loop
[14.6680579185, 10.0043799877][M: 14]: Start Serial Thread
[14.6703101013, 10.0066530704][M: 15]: Start launch loop
[25.6646039486, 21.0009260178][M: 16]: End launch loop
[25.6694090009, 21.0029489994][M: 17]: Main Thread End

Time From Boot     Time From Launch

Minor Bug: Multiple readings when establishing serial connection.

Test Serial Data Recording:
Project Imua 3
date = Mon Nov  7 23:50:10 2016
time_init = 1478598610.94

[14.6707530022, 10.0070750713][S: 0]: kStart Serial
[14.6738369465, 10.0105990157][S: 1]: Hello world!
[14.6758348942, 10.0121569633][S: 2]: Hello world!
[14.677889729, 10.014111042][S: 3]: Hello world!
[14.679859669, 10.016108036][S: 4]: Hello world!
[14.681789875, 10.0181119442][S: 5]: Hello world!
[14.6838328838, 10.020154953][S: 6]: Hello world!
[14.685839989, 10.022206068][S: 7]: Hello world!
[14.6879718304, 10.0242938995][S: 8]: Hello world!
[14.69099009, 10.026421070][S: 9]: Hello world!
[14.6922769547, 10.0285990238][S: 10]: Hello world!
[14.6944639683, 10.0307860374][S: 11]: Hello world!
[14.69668293, 10.0330049992][S: 12]: Hello world!
[14.6989400387, 10.0352621078][S: 13]: Hello world!
[14.9237940311, 10.2601161003][S: 14]: Hello world!
[15.9244480133, 11.2607700825][S: 15]: Hello world!
[16.9273438454, 12.263665145][S: 16]: Hello world!
[17.9267029762, 13.2630250454][S: 17]: Hello world!
[18.9310050011, 14.2673270702][S: 18]: Hello world!
[19.9305839539, 15.266906023][S: 19]: Hello world!
[20.934566021, 16.270888901][S: 20]: Hello world!
[21.9340949059, 17.270416975][S: 21]: Hello world!
[22.936880827, 18.2732028961][S: 22]: Hello world!
[23.9376160172, 19.2739400864][S: 23]: Hello world!
[24.9404389858, 20.276761055][S: 24]: Hello world!
[25.9399878979, 21.276309967][S: 25]: Hello world!
Test/Prototyping Plan (Data Controller)

Setup the analog accelerometer (sparrow28) → Do static testing → Test by launching on model rockets

Setup the digital accelerometer (kolea07) → Do static testing → Test by launching on model rockets

Setup the IMU (kolea08) → Do static testing → Test by launching on model rockets

Setup the analog sensors, serial streams and voltage level shifters → Test by connecting serial streams to other computers

Test the circuit board → Deliver to system integrators

Integrate entire subsystem onto one circuit board

Environmental Testing
Test/Prototyping Plan (Lookback Camera)

Set up all modules on bench

Verify automatic picture capture

Verify Wi-Fi link to RPi

Verify data transmission and storage

Physically integrate modules to ScubeR

Verify operation of limit switch upon ScubeR launch

Re-verify autonomous operation of modules

In Progress
Test/Prototyping Plan (Range Finder)

- Establish link between power and rangefinder
- Develop and test calculations for data processing
- Calibrate accuracy based on preliminary testing
- Integrate with aluminum housing
- Test rangefinder with simulated rocket release
- Test subassembly after integration with aluminum housing
- Deliver to system integrators
- Environmental Testing

In Progress
In Progress
In Progress
In Progress
In Progress
Complete
Analysis Results/Plans:

- Research is being done to determine the best adhesive for ScubeR’s assembly.
  - Previous adhesives have been too inflexible causing cracks and separation of ScubeR sections under stress.
- Analysis to determine which lenses are optimal for Onboard Mobius Cameras completed.
- Research is being done to determine which company is optimum for the printing of the Power Conditioning Board.
  - At this point we will be printing our circuit board using Express PCB, but we are still conducting ongoing research.
- Analysis was done to determine the correct model unit for the Flight Computer.
  - The Raspberry pi 2 model B was chosen since it is a legacy component from previous projects.
- Data controller subsystem
  - Using 5 volts for all devices on the subsystem
  - Using the Metro Mini 328 for the data controller due to its cost, size and it can be mounted easily on a printed circuit board. Since the subsystem wasn’t storing any data, this controller should be able to handle the load.
    - ADXL326 analog accelerometer have been using this sensor on various other projects since 2014.
    - LIS3DH digital accelerometer and the L3Gd20H+LSM303 IMU due to cost.
- Lookback Camera run-time needs to be analyzed using one 9v battery.
  - If run-time is insufficient, a second 9v battery can be added.
- Analysis was done on the detection angle and the optimal mounting position of Rangefinder.
5.0 Manufacturing Plan
Manufacturing Plan: Mechanical Elements

Mechanical Fabrication flow:

Subsystem Level Fabrication:
- ScubeR + Release Mechanism
- Onboard Camera assembly
- Power Conditioning Board
- Flight Computer
- Data Controller/Rangeﬁnder
- Outboard Camera assembly

Subsystem Testing Review: FEB

Integrated Systems Assembly:
- Assemble subsystems on payload deckplate
- Fabricate all electrical interfaces
- Verify center of Grav., weight and dimensions.


Environmental Testing:
- Mechanical stress test
- Vacuum chamber.
- Verify Release velocity of Rocket

Integration Readiness Review: Jun.

In house fabrication of subsystems in process. All components have been received or in acquisition.


2017 Aug <= 2017 Jun


Contingency for Action Items and potentially fatal failures.


Contingency for Action Items and potentially fatal failures.

Verify size, weight, center of gravity before IRR

Contingency for Action Items and potentially fatal failures.

Subsytem fabrication complete for ISTR
Manufacturing Plan: Electrical Elements

**Electrical Integration flow:**

**Subsystem Level Fabrication:**
- Power Conditioning PCB
- Data Controller/Rangefinder PCB
- Outboard Camera PCB

Subsystem Testing Review: FEB

**Integrated Systems Assembly:**
- Assemble interfaces for Payloads.
- Perform open bench testing, verify integrated operations
- Verify power budget
- Troubleshoot electrical failures


**Full Mission Simulations:**
- Verify deployments (ScubeR release)
- Verify Limit Switch Operation
- Verify electrical integrity before/after environmental testing

Integration Readiness Review: Jun.

PCB finalized and printed by Feb 1st. First PCB’S assembled for STR


Closed bench testing/ troubleshooting

2017 Jun <= 2017 Jun

2017 Aug <= 2017 Jun

PCB boards tested and operational for ISTR


Contingency for Action Items and potentially fatal failures.
Manufacturing Plan: **Software Elements**

**Software Development flow:**

- **Subsystem Level Development:**
  - Flight CPU
  - Data Controller/Rangefinder
  - Outboard Camera assembly

  Subsystem Testing Review: FEB


- **Integrated Systems Development:**
  - Establish data link between flight CPU and subsystems.
  - Create data structure for storage of flight data.

  Integrated Systems Testing Review: Mar. 19


- **Testing/Debugging:**
  - Run Full flight simulations
  - Collect and analyze data from simulations to verify integrity of operations.

  Integration Readiness Review: Jun. 03


  Integration readiness for full missions simulation


Contingency for Action Items and potentially fatal failures.

## Manufacturing Plan Overview:

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Components</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScubeR</td>
<td>--Rocket body</td>
<td>--De Laval nozzle - <strong>complete</strong></td>
</tr>
<tr>
<td></td>
<td>--stepper motor release</td>
<td>--Fuselage and plug - <strong>to be printed</strong></td>
</tr>
<tr>
<td></td>
<td>--De Laval nozzle - <strong>complete</strong></td>
<td>--stepper motor in-house - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--Fuselage and plug - <strong>to be printed</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>--stepper motor in-house - <strong>purchased</strong></td>
<td></td>
</tr>
<tr>
<td>Onboard Camera</td>
<td>--Mobius Cameras (4)</td>
<td>--Mobius Camera - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--Camera mounting brackets</td>
<td>--Camera mounting brackets - <strong>to be printed</strong></td>
</tr>
<tr>
<td>Power Conditioning Board</td>
<td>--(2) 5.0V 1312 DC-DC converters</td>
<td>--5.0V and 3.3V DC-DC converters - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--(2) 3.3V 1314 DC-DC converters</td>
<td>--power &amp; telemetry boards - <strong>to be fabricated and assembled</strong></td>
</tr>
<tr>
<td></td>
<td>--Printed Circuit Board</td>
<td></td>
</tr>
</tbody>
</table>

<Continued on next slide>
Manufacturing Plan Overview (Continued):

<Continued from previous slide>

<table>
<thead>
<tr>
<th>Subsystem:</th>
<th>Components:</th>
<th>Status:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Controller</td>
<td>--Metro Mini 328</td>
<td>--Metro Mini 328 - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--ADXL326 accelerometer (analog)</td>
<td>--ADXL326 accelerometer (analog) - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--LIS3DH accelerometer (I²C)</td>
<td>--LIS3DH accelerometer (I²C) - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--L3GD20H + LSM303 IMU (I²C)</td>
<td>--L3GD20H + LSM303 IMU (I²C) - <strong>purchased</strong></td>
</tr>
<tr>
<td></td>
<td>--Voltage level shifters</td>
<td>--Voltage level shifters - <strong>evaluating</strong></td>
</tr>
<tr>
<td></td>
<td>--Printed Circuit Board</td>
<td>--Printed Circuit Board - <strong>order placement within the week</strong></td>
</tr>
<tr>
<td>Outboard Camera</td>
<td>--Overo COM (WiFi)</td>
<td>--Overo COM - <strong>in house</strong></td>
</tr>
<tr>
<td></td>
<td>--Dual Camera Module</td>
<td>--Dual Camera Module and Limit Switch have been chosen - <strong>order placement within the week</strong></td>
</tr>
<tr>
<td></td>
<td>--Battery and Limit Switch</td>
<td>--3D Printed Housing - <strong>complete</strong></td>
</tr>
<tr>
<td></td>
<td>--3D Printed Housing</td>
<td></td>
</tr>
<tr>
<td>Rangefinder</td>
<td>--SF02/F laser infrared rangefinder</td>
<td>--SF02/F laser infrared rangefinder - <strong>purchased</strong></td>
</tr>
</tbody>
</table>
6.0 Testing Plan
Testing Plan: Mechanical Testing

Mechanical Testing flow:

Subsystem Critical Testing:
- Characterize Rocket Thrust in vacuum
- Demonstrate operation of ScubeR Release (photogate + ramp)
- Operation of stepper motor functions
- Perform stress analysis simulation for ScubeR/Outboard Camera
- Verify Release Velocity of Rocket

Integrated Systems Critical Testing:
- Open bench test
- Verify payload dimensions, weight, and Center of Gravity are within constraints.


Environmental Testing:
- Closed bench test
- Weight and Balance test
- Shake/spin test
- No mechanical inhibits

Integration Readiness Review: Jun.

Complete fabrication and assembly of ScubeR and Subsystems for ISTR


Contingency for Action Items and potentially fatal failures.


Make necessary modifications to mechanical layout. Complete payload assembly for testing

Contingency for Action Items and potentially fatal failures.
Testing Plan: Electrical Testing

Subsystem Critical Testing:
- Verify the operation of PCB’s provides correct voltages
- Verify Operation of Out-Cam Limit Switch

Integrated Systems Critical Testing:
- Open bench testing: Verify the assembly of electrical interfaces
- Collect data from each of sub-systems
- Simulate ScubeR release sequence

Environmental Testing:
- Verify the integrity of electrical interfaces after each phase of environmental testing
- No electrical inhibits

Integration Readiness Review: Jun.
Closed Bench testing prior to Envr. testing: Electrical testing with full payload assembly


Subsystem Testing Review: FEB

Boards to be fabricated during winter

Contingency for Action Items and system failures.

Testing Plan: **Software Elements**

**Software Testing flow:**

**Subsystem Critical Testing:**
- Verify data transfer from on/outboard cameras.
- Verify determination of ScubeR acceleration vector from image analysis and rangefinder data.
- Motion sensors testing will be done via the model rocket flights

**Subsystem Testing Review:** FEB

**Integrated Systems Critical Testing:**
- Integrated control software testing
- Integrated data transfer+storage
- Open-bench mission simulation

**Integrated Systems Testing Review:** Mar.

**Missions Simulation:**
- Verify successful deployment of ScubeR
- Characterize data integrity
- Test systems integrity
- No software inhibits

**Integration Readiness Review:** Jun.


7.0 User Guide Compliance
## Design Overview: RockSat-X User’s Guide Compliance

<table>
<thead>
<tr>
<th></th>
<th>Honolulu</th>
<th>Windward</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight?</strong></td>
<td>131.5g~Mobius Cam</td>
<td>~700 g.</td>
<td>~3000g excluding mounting hardware</td>
</tr>
<tr>
<td><strong>Dimensions?</strong></td>
<td>Cam 25mm x 45mm x 60mm Unknown for data controller at this time</td>
<td>Height = 40mm Base = 250 x 40mm</td>
<td>Within keepout space</td>
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<td><strong>Deployments?</strong></td>
<td>No</td>
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<td><strong>ADC Lines?</strong></td>
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<td>1</td>
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<td><strong>Async/Parallel?</strong></td>
<td>Yes/No</td>
<td>No/No</td>
<td>Yes/No</td>
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<td><strong>Power/Timer Events?</strong></td>
<td>TE-1 @ T= 0.1+ GSE @ T= -300s</td>
<td>TE-1 @ T= 0.1+</td>
<td>TE-1 @ T= 0.1+ GSE @ T= -300s</td>
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<tr>
<td><strong>Understand CG Requirement?</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td><strong>High Voltage?</strong></td>
<td>No</td>
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<td><strong>Hazardous Procedures?</strong></td>
<td>No</td>
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<td>No</td>
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<tr>
<td><strong>RF?</strong></td>
<td>No</td>
<td>Yes (Hammerhead)</td>
<td>2.4GHz WiFi</td>
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<td><strong>Bottom of Deck Plate Flush?</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>US Persons for whole team?</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>ITAR?</strong></td>
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<td>Compliant</td>
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</table>
## User Guide Compliance: Power Interface

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<tr>
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<th>Intended Use</th>
<th>Compliant</th>
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<tbody>
<tr>
<td>1</td>
<td>GSE 1</td>
<td>Supply power to Flight Computer (WinCC) and H-Bridge (WinCC)</td>
<td>Yes</td>
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<td>2</td>
<td>Timer Event Redundant (TE-RA)</td>
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<td>4</td>
<td>Timer Event 1 (TE-1)</td>
<td>ScubeR Stepper Motor (WinCC), Rangefinder (WinCC) and Onboard Cameras (HonCC)</td>
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<tr>
<td>5</td>
<td>GND</td>
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## User Guide Compliance: Telemetry Interface

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<th>Function</th>
<th>Intended Use</th>
<th>Pin</th>
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<tbody>
<tr>
<td>1</td>
<td>Analog 1</td>
<td>Rangefinder (WinCC)</td>
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<td>2</td>
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<td>37</td>
<td>Ground</td>
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</table>
8.0 Project Management Plan (PMP)
PMP: Team Organization Chart

Joseph Ciotti
Science PI / Lead Co-I
Project Manager
WinCC

Marcia Rei Nii
Executive Director HSGC

Luke Flynn
PI / Director HSGC & Hawai’i Space Flight Lab

Jacob Hudson Jr.
Co-I / Mentor
Sublimation Rocket
Integration/ Static Testing
WinCC

Michael Ferguson
Interim Co-I
Camera / IMU
HonCC

Will Smith
HonCC Mentor

Helen Rapozo
IT / Documentation Specialist
HonCC

WinCC Students
Cale Mechler
(lead student)
Pingyang Liu
Damien Apilando

HonCC Students
Onkar Nerurkar
(lead student)
Syrus Valdivia

KauCC Student
Nick Herrmann
(Hammerhead)

Bob Potter
HonCC
Industry Mentor

2017
CDR
100
### Gantt Chart UHCC RockSat-X 2017

**(revised 12-5-2016)**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
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<td>Flight Computer</td>
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<td>Sub-System test</td>
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<td>Full Mission Simulation</td>
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**Review/Telecon**

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<tr>
<th>CoDR</th>
<th>PDR</th>
<th>CDR</th>
<th>Manifested?</th>
<th>STR</th>
<th>ISTR</th>
<th>FMSR</th>
<th>IRR</th>
<th>ETS</th>
<th>LRR</th>
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<td>HonCC</td>
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<td>Hammerhead</td>
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</table>
PMP: Team Mentors

University of Hawai‘i Community College (UHCC) Project Imua

**RS-X 2017 Team Mentors & Consultants**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Mentor/Consultant</th>
<th>Cell Phone</th>
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<tbody>
<tr>
<td><strong>Windward CC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WinCC Co-I/Project Manager</td>
<td>Joseph Ciotti</td>
<td>808-225-5637</td>
</tr>
<tr>
<td>WinCC Co-I/Mentor</td>
<td>Jacob Hudson</td>
<td>808-347-8246</td>
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<tr>
<td><strong>Honolulu CC</strong></td>
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<tr>
<td>HonCC Designated Co-I</td>
<td>Michael Ferguson</td>
<td>808-457-8331</td>
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<tr>
<td>HonCC Mentor</td>
<td>Will Smith</td>
<td>808-561-3692</td>
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<td>HonCC IT Specialist/Mentor</td>
<td>Helen Rapozo</td>
<td>808-367-3684</td>
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<td>HonCC Industry Mentor</td>
<td>Robert Potter</td>
<td>808-797-0851</td>
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<td><strong>UH Mānoa</strong></td>
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<tr>
<td>HSGC/HSFL Director/Imua PI</td>
<td>Luke Flynn</td>
<td>808-277-7218</td>
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<tr>
<td>HSGC/ Program Coordinator/Executive Director</td>
<td>Marcia Rei Nii</td>
<td>808-384-4684</td>
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*revised 10-9-16*
RockSat-X 2017 Budget: UHCC Project Imua

*rev 12-5-16*

UHCC Project Imua

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<tr>
<th>Item</th>
<th>Year 3 (2016-17)</th>
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<tr>
<td></td>
<td>Budgeted</td>
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<tr>
<td>Student Fellowships (Fall/Spring)</td>
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<td>Student Summer Travel Stipend</td>
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<td>Other Travel</td>
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<td>Supplies total</td>
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<td>RockSat-X 2017 launch fee deposit¹</td>
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<td><strong>Total</strong></td>
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¹Launch fee deposit check ($2,000) mailed on 10-12-16
### RS-X 2017 Contact Matrix

<table>
<thead>
<tr>
<th>Team Name/School: University of Hawai‘i Community College (UHCC) Project Imua</th>
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<tbody>
<tr>
<td><strong>Windward CC</strong></td>
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<tr>
<td><strong>Role</strong></td>
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<tr>
<td>Windward CC</td>
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<tr>
<td>WinCC Co-I/Project Manager</td>
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<tr>
<td>WinCC Co-I/Mentor</td>
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<tr>
<td>WinCC Lead Student</td>
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<td>WinCC Student</td>
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<td>WinCC Student</td>
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<td>KauCC Student</td>
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<td>HonCC Industry Mentor</td>
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<td><strong>UH Mānoa</strong></td>
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<tr>
<td>HSGC/HSFL Director/Imua PI</td>
</tr>
<tr>
<td>HSGC/ Program Coordinator/Executive Director</td>
</tr>
</tbody>
</table>
PMP: Concerns & Mitigation

• **Concern 1**: Sublimation Rocket may not clear CarRoLL before re-entry.
  
  ❖ **Mitigation**: Use of worm gear will guarantee clearing of CarRoLL section.

• **Concern 2**: The Specific Impulse of the sublimation propellant is unknown, resulting in an uncertainty of rocket’s maximum mass.
  
  ❖ **Mitigation**: Once a prototype ScubeR is constructed, it will be loaded with varying concentrations of different sublimation propellant and tested inside a vacuum chamber at the Hawai‘i Space Flight Lab in Honolulu.

• **Concern 3**: Infrared Rangefinder’s narrow beam may become undetectable if ScubeR and CarRoLL drift into different orientations near apogee.
  
  ❖ **Mitigation**: emitted beam may be diffused into a wider cone for detection over a larger field of view.
PMP: Conclusions

• **Mission should fly because:**
  
  We have shown a viable set of experiments for a suborbital launch and have either fulfilled our objectives for flight or are currently in a progressive stage of completion for each.

• **Next steps for our team to get to STR:**
  
  – Begin assembly of ScubeR body and heating element integration.
  
  – **Mobius camera system:** Take apart the cameras, Mount circuit boards in Hammond box, configure software.
  
  – Complete arrangement, construction, testing of **Power Conditioning Board**.
  
  – 3D print CAD files for **Lookback Camera**, test battery run-time with heating coil in open bench test.
  
  – **Flight Computer**: integrate image recording code into a separate thread.
  
  – Connect and integrate **Rangefinder** with data controller.
  
  – **Data controller**: Add voltage level shifters.
Acronyms

PrIMEAT – Project Imua Multiple Experiment Attempt Two … (pronounced *primate*)

HonCC – Honolulu Community College

KauCC – Kaua‘i Community College

WinCC – Windward Community College

UHCC – University of Hawai‘i Community Colleges

HSGC – Hawai‘i Space Grant Consortium

HSFL – Hawai‘i Space Flight Lab

ScubeR – Super Simple Sublimation Rocket (S$^3$R)

PCB – Power Conditioning Board
sparrow28 is used to test out the ADXL326 accelerometer on a model rocket.

kolea04 is used to help test out programs that generate circuit board layouts.

kolea05 is being used on the PrIMEAT payload as the data controller subsystem.

kolea07 will test the LIS3DH accelerometer on a model rocket

kolea08 will test the L3GD20H+LSM303 IMU on a model rocket.

Hammerhead – Outboard lookback cameras

Mobius – Onboard cameras
Team Pictures

Honolulu (HonCC)

Windward (WinCC)

Kaua‘i (KauCC)