Full Mission Simulation Report

Old Dominion University
Monarch- One
19 May 2015
The Monarch-One Payload
1.0 Mission Overview

Brian Ferguson
Mission Overview

- Monarch-One will successfully gather flight data and transmit the flight data via transmitter during flight to ODU’s Satellite Communications System (SCS), while measuring the power output of a solar cell that is exposed to the full spectrum of the sun’s light.
ConOps

Altitude vs. Time

- **t ≈ 0.6 min**
  - End of Orion Burn
  - Altitude: 52 km
  - G switch triggered
  - All systems on
  - Begin data collection and transmission

- **Apogee**
  - t ≈ 2.8 min
  - Altitude: ≈115 km

- **t ≈ 20 min**
  - Splash Down
  - End data collection and transmission

- **t ≈ 4.0 min**
  - Altitude: 95 km

- **t ≈ 5.5 min**
  - Altitude: 52 km
  - Chute Deploys
ConOps

- Data retrieval will begin immediately.
- Data collection and accompanying acquisition via SD card will occur throughout entire flight.
- Transmission will begin immediately.
  – Thanks Becca!
- Payload will stop collecting data after 20 minutes, anything longer is not needed.
IntegratedSubsystemTestingStatus:

- Integrate and test transmitter________________________✓
- Test data collection code__________________________✓
- Software system code______________________________✓
- Develop PCB’s and perform functionality tests ______✓
- Calibrate Current Sensor____________________________✓
- Correct functional pinout of solar cell _______________✓
- Integration of solar cell onto PCB____________________✓
- Manufacture Makralon plates to correct size__________✓
- Plate integration with can model____________________✓
- Manufacture antenna ______________________________In work
- Manufacture brackets for mounting _________________In work
- Multiple successful iterations of subsystems prior to integrated testing________✓
- Fully integrated vibration testing in house @ ODU ____In work

BLUE FONT -> Mechanical Team specific
GREEN FONT -> Electrical Team specific
2.0 Integrated Subsystem
Testing Status

Transmitter – Jason Harris
Code Testing – Connor Huffine
PCB Testing – Cameron Kowaki
Solar Testing – Ashley Smith
Mechanical Systems – Adam Horn
Canister Integration – Cian Branco
Vibration Testing – Edward Conley
Subsystem: Transmitter

- Chosen radio meets requirements for needed power output, solves internal amplifier problem, and transmits at 436MHz
- Requires a 5mV signal from microcontroller
- Teensy 3.1 has built in DAC; can generate signal needed
Pictures – Transmitter Signal Analysis

5 volt signal represents the 5 volts supplied from Arduino

At right is a 100mV peak-peak signal (50mV pulse) -> voltage divider needs to be altered to attain 5mV (10mV peak-peak)
Transmission Testing Status

Subsystem: Transmitter
Transmission programming has been tested with data being transmitted.

Demodulated Signal from Data Transmission
Subsystem: Software - Solar Cell Code Testing

• // Current and Voltage Testing
• // Reads current and voltage of a solar cell using analog pins
• // turns MOSFET on to measure short circuit current

void setup() {
//pin 2 is used to turn the mosfet on and off
pinMode(2, OUTPUT);
digitalWrite(2, 0);
Serial.begin(9600);
}

void loop() {
float temp;
//calculate voltage
Serial.write("Voltage = ");
temp = analogRead(0);
temp = temp * 0.0048;
Serial.println(temp);
delay(1000);
//turn MOSFET on and measure current
digitalWrite(2, 1);
delay(100);
Serial.write("Voltage = ");
temp = analogRead(0);
temp = temp * 0.0048;
Serial.println(temp);
delay(1000);
//turn MOSFET back off
digitalWrite(2, 0);
delay(100);
}
*solar cell picture is NOT the one being flown, this is a sensor and code test using a basic solar cell from RadioShack
Software Subsystem Testing Status

Subsystem: Software
Flight data acquisition is displayed below with program flowchart, actual testing results are shown on the left.
Software Testing Status:

Subsystem: Software

Flight data collection program was tested with great success using breakouts on the breadboard individually before PCB integration.
Subsystems: PCB Testing Status

- At left is our updated Arduino PCB shield
- Teensy footprint was added
- Component footprints are correct and functional
- RGB LED, logic shifter, connections to other boards were added
Subsystems: PCB Testing Status

- Power Distribution Board revision seen at right.
- Made to include revised/fixed ARM signal and G-Switch circuits.
- Includes 3.3v and 5v regulators for distribution to Arduino shield
Subsystem: PCB Testing Status

- Created separate board for solar measurements
- Opened up room on Shield board for Teensy
- MOSFET switches open/closed for data collection
- Communicates with Arduino
Subsystem PCB Testing Status:

Subsystem PCB’s

- Optical PCB is good, no revision was needed.
- Shield PCB revision op check good on USB and battery power.
- Power PCB revision made op checks good on battery power.
Electrical: Current Sensor Calibration Complete

• Successful calibration measures milliamp level current generation
• Reference voltage is set to output of sensor
• Very large gain needed for readable outputs i.e. ~47x
Electrical Subsystem Testing Status:

Subsystem: Electrical

Flight data collection has been tested with great success.

Solar Cell has been tested with great success and is completed.

Individual sensors and components were found to operate as advertised without issue.
Subsystem: Solar Cell Simulations

- Lab tests under simulated sunlight
- Simulation analysis portrays the cells characteristics
- Developed IV curves illustrate this behavior
- This data will be compared with actual flight measurements
- AM0 analysis will be available post flight.
- Degradation effects will be available post flight.
Subsystems: Solar Cell Simulations

IV Curve Testing System
Solar Cell Testing Status:

- In order to determine the correct pin out of the solar cell, we had to check the diode resistance of each pin.

<table>
<thead>
<tr>
<th></th>
<th>RED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<td>15</td>
<td>x</td>
</tr>
<tr>
<td>16</td>
<td>x</td>
</tr>
</tbody>
</table>
Solar Cell Testing Status:

- The results from the multimeter gave us the following pinout on the right.
- From this pin out we were able to perform tests on the cell using the setup below.
Solar Cell Subsystem Testing Status:

Pre-flight in-lab simulations demonstrates the expected results from the cell when exposed to light.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Voc [V]</td>
<td>0.1083</td>
</tr>
<tr>
<td>Voc/seg [mV]</td>
<td>108.349</td>
</tr>
<tr>
<td>Isc [A]</td>
<td>2.28E-03</td>
</tr>
<tr>
<td>Jsc [mA/cm²]</td>
<td>36.553</td>
</tr>
<tr>
<td>Jsc/seg [mA/cm²]</td>
<td>36.553</td>
</tr>
<tr>
<td>Fill Factor [%]</td>
<td>41.15</td>
</tr>
<tr>
<td>Pmax [mW]</td>
<td>1.02E-01</td>
</tr>
<tr>
<td>Vmax [V]</td>
<td>7.09E-02</td>
</tr>
<tr>
<td>Imax [mA]</td>
<td>1.44E+00</td>
</tr>
<tr>
<td>Rshunt est [W]</td>
<td>9.80E+01</td>
</tr>
<tr>
<td>Voc slope [W]</td>
<td>1.46E+01</td>
</tr>
<tr>
<td>Efficiency [%]</td>
<td>1.63</td>
</tr>
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</table>
Solar Cell PCB Testing Status:

- In lab testing generated results demonstrated the expected results from the solar cell
- From these results, we soldered the solar cell to the PCB and successfully recorded data
Mechanical Subsystem Testing Status:

Subsystem: Plates

- Makralon has been cut by the machine shop to the appropriate size
- 2 12”x48” sheets will yield 8 plates
Mechanical Subsystem Testing Status:

Subsystem: Plate Configuration

The holes have been drilled into the makralon and the plates have been attached to one another in flight configuration.
### Mechanical Subsystem Testing Status:

#### Subsystem: Mass Budget

<table>
<thead>
<tr>
<th>RockSat Mass Budget</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Batteries</td>
<td>1.524 lbs.</td>
</tr>
<tr>
<td>Brackets</td>
<td>1.276 lbs.</td>
</tr>
<tr>
<td>Plate</td>
<td>0.376 lbs.</td>
</tr>
<tr>
<td>Shield</td>
<td>0.088 lbs.</td>
</tr>
<tr>
<td>Power Shield</td>
<td>0.088 lbs.</td>
</tr>
<tr>
<td>Arduino</td>
<td>0.088 lbs.</td>
</tr>
<tr>
<td>Memento Box</td>
<td>1.000 lbs.</td>
</tr>
<tr>
<td>G-switch</td>
<td>0.100 lbs.</td>
</tr>
<tr>
<td>Transmitter</td>
<td>0.551 lbs.</td>
</tr>
<tr>
<td>Plate</td>
<td>0.376 lbs.</td>
</tr>
<tr>
<td><strong>Total Mass</strong></td>
<td><strong>5.467 lbs.</strong></td>
</tr>
<tr>
<td><strong>Center of Gravity</strong></td>
<td>~0.98&quot;</td>
</tr>
</tbody>
</table>

**75%**
Mechanical Subsystem Testing Status:

Subsystem: Mass Budget

The mass budget of the rocket will achieve the required 6.5 +/- .1 lb with the addition of the metal brackets holding the batteries down in addition to the memento box.

![Image of a digital scale reading 5.0418]
Mechanical Subsystem Testing Status:

Subsystem: Brackets, Antenna

- Bracket, Antenna measurement spec’s are in inventor
- Machine shop has the aluminum/steel needed
- Awaiting brackets from machine shop for final assembly
- Awaiting antenna from machine shop as well
Mechanical Subsystem COG Analysis:
Mechanical Canister Integrated Model
Plans for In-House Vibration Testing

- Payload will be permanently built prior to test
- Complete payload will be suspended using rubber bands
- Powered speaker will be used to vibrate a rod connected to payload
- Tone generator can generate both sine and random frequencies
3.0 Full Mission Simulation Results

Brian Ferguson
Cameron Kowaki
Full Mission Simulation Results

• Testing Setup
• Batteries connected to power distribution board
• Power lines run to Arduino shield and transmitter
• Current sensor board connected to Arduino shield
Full Mission Simulation Results

- Full simulation tests are run for 1 minute intervals
- Conserves battery life
- Fully functional test
- Transmitted data should be seen from ODU ground station
Full Mission Simulation Results

• Initial power connection to the transmitter proved faulty

• Improvements include use of an opto-isolater and capacitor for the circuit

• This method successfully turned the transmitter on and off as desired when instructed by our program
Full Mission Simulation Results

- Transmitter harness needed to be reduced for successful implementation.
- Connections needed revision.
- Use of the hand dryer was used with much success.
Full Mission Simulation Results

• Tests were performed by the group at ODU producing the following results:
  – The payload successfully takes/saves data to the SD card
  – Data is successfully transmitted

• These tests were run several times for the durations of 1 minute. Run time just needs to be changed for flight time.
Full Mission Simulation Results

Transmission:
– The payload successfully transmitted during breadboard testing and while the components were separate.
– With all the components together, the transmitter causes the entire shield to fail due to RF interference.
Full Mission Simulation Results

- Antenna was removed from the transmitter
- Payload tested good and did not fail even with radio close (payload conditions)
- Tests with coax will be conducted when port arrives from Wallops
Full Mission Simulation Results

• Action items left before the LRR?
  – Run tests with coax and fabricated antenna and confirm no interference
  – Attach components to the Makralon plates using fabricated brackets from ODU machine shop (Permanent install)
  – Perform vibration tests in house at Old Dominion University
4.0 Project Management Update

Ashley Smith
Action Item Summary

- Canister Integration – May 11th
- Electrical Transmitter – May 28th
- Bracket Integration – May 28th
- Vibe Testing at ODU – Prior to June 4th
- Launch Readiness Review – June 4-10th
- Travel to Wallops – June 17th
## User Guide Compliance

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can?</td>
<td>~.98&quot; currently</td>
</tr>
<tr>
<td>Contained in can</td>
<td>Yes</td>
</tr>
<tr>
<td>Connected to can by 4/5 bulkheads on top and bottom only</td>
<td>Currently do not have plans for mid plate</td>
</tr>
<tr>
<td>Mass at 20±0.2lbs</td>
<td>Our payload is at 5.04 lbs</td>
</tr>
<tr>
<td>Shared canister clearance</td>
<td>1” separation between payloads</td>
</tr>
<tr>
<td>No voltage on the can</td>
<td>Payload is electrically isolated</td>
</tr>
<tr>
<td>Activation wires at least 4 ft</td>
<td>10+ ft of various color wire will be brought to Wallops</td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td>22 gauge</td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td>Not using</td>
</tr>
<tr>
<td>T-0 Activation: current &lt; .1 A</td>
<td>G-Switch &lt;. 100mA</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Lithium Polymer (will not charge at Wallops)</td>
</tr>
</tbody>
</table>
Shared Can Logistics

• We are sharing with the Community College of Denver
  ➢ Their objective: Develop, test, and implement a computer controlled electromagnetic counter rotation platform mounted inside of a spin stabilized rocket. To counteract the rotation of the rocket to cancel centrifugal forces on their spin platform.

• Plan for collaboration
  – We have determined email to be our primary source of communication.
  – POC: Matt Hevert, RockSat CCD
  – No physical fit checks will be performed until we meet at Wallops

• Not using mid-mount plate
• 1” between payloads IAW RSC 2015 User Guide
• CCD will not be using ports, payload is contained in canister.
• ODU will use optical and special port
## Transaction - Last 12 months

2/24/2014 through 2/23/2015

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<td>Opening Balan...</td>
<td>[Rocket Sat] R</td>
<td>Lab Equipment</td>
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</table>
Conclusions

• Transmission issues need to be worked out.
• Vibration tests at ODU will provide indication on how the payload will react under testing at Wallops.
• Check-In Portfolio to be started June 1st

Questions?
A rough estimate of power required can be found by using a link budget. A link budget is an equation which adds up all the gains and losses in the system. The most basic link budget equation is shown in Equation-1.

\[
Pr = Pt + Gt + Gr + Lp \quad (1)
\]

Here, \( Pr \) is the received power in dBm (decibels per milliwatt). \( Pt \) is the transmitted power in dBm. \( Gt \) is the gain of the transmit antenna relative to that of an isotropic antenna (an antenna that radiates power equally in all directions) in dBi. \( Gr \) is the gain of the receive antenna relative to that of an isotropic antenna in dBi and \( Lp \) is the path loss in dB.
Appendix A – Transmitter Calculations

• The path loss in free space can be approximated by using Equation-2. \( \lambda \) is the wavelength of the transmitted frequency (in meters) and \( d \) is the distance (in meters).

\[
L_p = 10 \log_{10} \left( \frac{4 \ d}{\lambda} \right)^2 \quad (2)
\]

• The transmitter that is currently being investigated is the MICRF112-433 evaluation board. This system supports a power output of 10 dBm according to the datasheet. If the power level was given in watts, Equation-3 could be used to convert it to dBm.

\[
P_{dBm} = 10 \log_{10} \left( \frac{P_w}{10^{-3}} \right) \quad (3)
\]
Appendix A – Transmitter Calculations

• The UHF antenna installed on top of the roof of Kaufman Hall has a gain of 15.5 dBi. It is assumed that the antenna that will be on the rocket will have 0 dBi of gain and the rocket will be approximately 180km from Old Dominion University. The wavelength is approximately 0.7 meters as shown in Equation-4.

\[ \lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{m/s}}{433 \times 10^6 \text{Hz}} = 0.7 \text{m} \quad (4) \]

• Using the values in Table-1, the received power is calculated to be -104.688 dBm as shown in Equation-5.

\[ P_r = 10 \text{dBm} + 0 \text{dBi} + 15.5 \text{dBi} - 130.188 \text{dB} \]
\[ = -104.688 \text{dBm} \quad (5) \]
Appendix A – Transmitter Calculations

Table 1: Values of Link Budget Calculation

<table>
<thead>
<tr>
<th>Pt</th>
<th>10 dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gt</td>
<td>0 dBi</td>
</tr>
<tr>
<td>Gr</td>
<td>15.5 dBi</td>
</tr>
<tr>
<td>Lp</td>
<td>130.188 dB</td>
</tr>
</tbody>
</table>

The sensitivity (the smallest signal the radio can detect) of the IC-9100 transceiver is approximately -107 dBm. If we assume the cable losses are approximately 3 dB, the received power from the transmitter will then be -107.688 dBm. In order to reliably receive the signal at ODU, we will need to add an amplifier to the transmitter.