Space Flight Design Challenge
Conceptual Design Review

FSU, BRCTC, NASA PAXC, & WVU-ARC
Jeffrey Moe, Jeff Reynolds, Emily Certain, Sebastian Reger, Ronald Willis
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- Concept of Operations

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Fairmont State University
Mission Overview

Emily Certain
• Mission statement
  – The goal of the project is to track the rocket using a ground station and model the trajectory as the rocket launches and proceeds on its intended flight path.
Objective: Collect data and transmit to a ground station for modeling of the rocket in real time

Project requirements → derived from mission statement
- To determine the feasibility of a ground station and transmitter
- Determine all required components to ensure proper setup of devices
- Data collection system
- Create a transmitting system that accurately collects data

Minimum success criteria
- Minimum success: to gather the data without transmitting to a ground station. This can then be modeled at a later date
As the rocket takes off, there are 3 planes which will be tracked. These planes will help model the rocket on a program or physical model. We can also track the spin rate and model it in real time. As the duration of the flight increases, we can see the change in its flight path as it reaches its highest altitude and begins to fall.
The expected results will be similar to data acquired by Wallops Flight Facility. At apogee, the rocket should level off and being to tilt down as it descends. It will also slow down and come to brief halt before beginning to descend back towards the water.
FSU Con-Ops

Altitude

High Concentration of N2
- $t \approx 1.3$ min
- Altitude: 75 km

Apogee
- $t \approx 4.0$ min
- Altitude: \approx 115 km

High Tumble Rate
- $t \approx 5.5$ min
- Chute Deploys

Low N2, Low spin
- $t \approx 15$ min
- Splash Down

End of Orion Burn – Spin Rate Largest
- $t \approx 0.6$ min
- Altitude: 52 km

Splash Down
- $t \approx 15$ min
- All systems on
- Begin data collection
DESIGN OVERVIEW

Major technology dependencies:

- Digi XLR PRO Module
  - Frequency Range – ISM 902 to 928 MHz
    The frequency falls within amateur radio allocation.
  - Max transmitting power
    +30 dBm (1 watt)
  - RF Data Rate
    9.4 kb/s to 3.2 Mb/s
  - Operating voltage
    3.8 to 5.5 VDC
- 3 axis accelerometer
- Arduino mini
- Gyroscope
RISKS AND WORRIES

- The DIGI transmitter may not be functional at the time of integration.

- Biggest worries is having the transmitter and ground station complete in time.
CONCLUSION

- Need to determine the feasibility of the transmitter on the rocket and create a model transmitter using a cheaper device.
Conceptual Design Review

NASA PAXC (All Centers)
MISSION STATEMENT

• Mission statement
  – The goal of our project is to prototype a CubeSat payload (same footprint) that will perform tasks such as collecting and analyzing data without direct contact between the instrument and the object being analyzed (Earth); Remote sensing.
    – This design is to be later implemented and used on a real CubeSat
• Project requirements
  – Measure reflected RF signals (Reflectometry) to measure the properties of a medium in which signal waves are propagated

• System Requirements
  – Need a data collection system to store the measurements (for redundancy)
  – Ground Station

  – Minimum success criteria
    – Receive data in general on the ground in general
THEORY AND CONCEPTS

• Reflectometry

• A technique in which properties of a medium through which signal waves propagate are measured
  • When waves encounter discontinuities, part of that energy is reflected back and another part is transmitted through the medium
  • By analyzing the reflected signal, we will find more information about the medium or the interface itself
EXPECTED RESULTS

• As our apparatus tests propagations, we expect to receive reception from various points on the Earth’s surface.

• As the mission goes on, we expected to gather accurate data pertaining to the trajectory/flight path of the rocket to then be compared to that of Wallops’
EX: CONOPS FOR “PROJECT E”

Altitude

High Concentration of N2
\( t \approx 1.3 \text{ min} \)
Altitude: 75 km

Apogee
\( t \approx 2.8 \text{ min} \)
Altitude: \( \approx 115 \text{ km} \)

High Tumble Rate
\( t \approx 4.0 \text{ min} \)
Altitude: 95 km

End of Orion Burn – Spin Rate Largest
\( t \approx 0.6 \text{ min} \)
Altitude: 52 km

-G switch triggered
-All systems on
-Begin data collection

Low N2, Low spin
\( t \approx 5.5 \text{ min} \)
Chute Deploys

\( t = 15 \text{ min} \)
Splash Down
• What are the major components in your design?
  – Structure:
    • Standard CubeSat footprint PCB
  – Major technology:
    • A pair of COTS software-defined radio dongles (RTL-SDR)
    • Accelerometers to track the rocket’s motion & trajectory
    • Data uplink patch antenna
    • System computer (Raspberry Pi)
RISKS AND WORRIES

- Obtaining the RF signal data on the ground
- Mass Communication platforms and strategies will need implemented to complete work because we will be obtaining deliverables from 9 centers
Community & Technical College
Mission Overview
MISSION STATEMENT

• Mission statement
  – The goal of PiGen2 is to successfully record an accurate vibration profile of the rocket in order to construct a Power Spectral Density report.
    – A gyroscope and accelerometer will be used to provide information on speed and orientation.
MISSION OBJECTIVES

• Project requirements

  – There are 4 subsystems in PiGen2. The first subsystem is the Raspberry Pi, which is the hub and data storage.
  – The second subsystem is the Accelerometer that will measure the speed and acceleration data.
  – The third subsystem is the Gyroscope that will measure orientation data.
  – The last and mission critical subsystem are the Piezoelectric actuating transducers that are required to produce vibration data.

• Minimum success criteria

  – Mission success is only achieved if we retrieve accurate vibration data on at least one axis. All other data is secondary.
THEORY AND CONCEPTS

• PiGen uses the Piezoelectric effect to measure vibrations via an oscillating crystal (ceramic tab), producing a voltage which is measured and then converted into vibration data.

• The accelerometer and gyroscope uses a the piezoelectric effect also by measuring the oscillations of crystals to measure a voltage, which is then converted into relevant data.

• The piezoelectric effect has been researched heavily in the past year. All devices have been researched extensively as well.

• Only circuit board creation requires more research. I am in the process of learning the proper ways to lay trace on a PCB.
EXPECTED RESULTS

– We expect to see a voltage that varies proportional to the variable hertz exerted by the rocket.
– We expect to see some noise in the accelerometer and gyroscope data because of the hertz exerted by the rocket.

We expect to see a stronger hertz reading during the initial burn of both engines and then we expect to see the hertz taper off a bit as the rocket leaves the atmosphere and the influence of wind sheer. We expect to see ambient vibration data as the rocket reaches apogee and then a change in vibration data as the rocket journeys back down to the surface without the influence of the engine.
**BRCTC Con-Ops**

**Hertz range shrinks**
- $t \approx 1.3\,\text{min}$
- Altitude: 75 km

**Ambient Hertz of rocket at apogee**
- $t \approx 2.8\,\text{min}$
- Altitude: $\approx 115\,\text{km}$

**End of Orion Burn – Spin Rate Largest,**
- Hertz range begins
- To taper after this point
- $t \approx 0.6\,\text{min}$
- Altitude: 52 km

**High Tumble Rate**
- New hertz range
- $t \approx 4.0\,\text{min}$
- Altitude: 95 km

**Chute Deploys**
- Initial and second burn.
- Strongest hertz expected to be seen in this range.

**t = 0\,\text{min}**
- Power engaged upon NASA power up
- All systems on
- Begin data collection
- Accelerometer and Gyroscope will send data until power is turned off.

**t \approx 5.5\,\text{min}**
- Natural hertz range of rocket (open or closed) without engine interference

**t \approx 15\,\text{min}**
- Splash Down
- End data collection
DESIGN OVERVIEW

Structure:
- Single PCB inside of an ABS 3D printed case.

Major technology dependencies:
- Actuating piezoelectric transducers with a vibration collection range up to 2,000 hertz, +/- 3g gyroscope, +/-50g accelerometer, Raspberry Pi 3.
Electrical:

- We need one line of 5V power for the ADIS gyroscope and all other devices will receive a 3.3V power line from the Raspberry Pi, which will be receiving it’s own 5V power line. All data will go to the raspberry pi.

Heritage Elements

- We will be using the same parts as last year, with a few replacements. The only changes in the design are a lack of redundancy to declutter the PCB, an adjusted PCB design and an adjusted ABS case design.
BRCTC-FBD

Power

Raspberry Pi

Memory Card

ADC

ADIS 6 DOF Gyroscope

Piezo 1

Piezo 2

Piezo 3

RBF (Wallops)

Power

Data
Preliminary layout has all boards close to together, with the ADIS and ADC on separate sides to prevent the cluttering of data lines. The piezoelectric actuating transducers will be oriented to capture the X, Y and Z axis. Upon prototyping we will decide the orientation.
RISKS AND WORRIES

All devices survived the 2017 launch, so no risk factors exist within the design. We have decided to simplify the experiment this year to prevent issues.
CONCLUSION

• The only research required right now is PCB trace rules and physics.
West Virginia University
Amateur Radio Club
Design Overview
MISSION OBJECTIVES

• Project requirements
  – Method of telemetry collection
  – Transmitting station aboard RockSat
  – Receiving station at launch site
  – Several receiving stations to determine propagation

• Minimum success criteria
  – Reception of telemetry data during any part of the flight
THEORY AND CONCEPTS

• Amateur Radio operators around the world transmit data daily over several established data protocols.
• White paper published by the ARRL describes the Doppler shift experienced by rockets moving at high velocity.
EXPECTED RESULTS

• Receive mission telemetry from
  – Base station at Wallops
  – Several scattered reception stations throughout the East Coast
CONCEPT OF OPERATIONS

• During the entire flight, telemetry data will be collected and transmitted.
  – Data collection will occur from activation at t-3 minutes until the end of the flight
  – Transmission will cease when velocity reaches 0
• Major Components
  – Structure
    • Several PCB’s
    • Antennas
  – Major technology dependencies
    • For telemetry data collection:
      • Two major options, GPS and inertial
      • GPS is preferable, but leads to complications
      • Commercial units stop operating at 60,000 ft. and 1200 MPH
DESIGN OVERVIEW CONTINUED

• Major Components (cont’d)
  – Electrical
    - Provide power to microcontroller and radios in order to collect and transmit data
  – RF
    - Two Software Defined Radios (SDR’s) and two antennas used to transmit on independent frequencies
      • Redundancy for the telemetry and propagation studies
Functional Body Diagram
RISKS AND WORRIES

• What to do about flying our own GPS unit given the operational parameters
• Tracking the rocket in flight.
Using the same mechanical layout for our payload as last year -
Includes:
- Makrolon Plates
  - 4 subsystems on the bottom and 3 on top along with the power distribution board

Only change:
- We will be utilizing a mid mounting plate this year
System Overview: Payload Layout

**System Components:**
- WVU-ARC
- FSU
- BRCTC
- PAXC

**Power Distribution System:**
- T-3 min activation switch (Wallops)
- Low Voltage 4.0 V
- Voltage Regulation +/- 12V
Design Overview: Ports

Thus far, we have requested:

- Multipurpose Port
- Atmospheric Port

Reasoning:

-The WVU-ARC Team is unsure of which would be a best fit for their small antenna for their RF propagation study so we requested both just in case
Predicted mass
- Based on last year, our predicted weight is 5 lbs (rest ballasted)

Predicted volume
- We will be fitting in a half can

We will be using a T-3 Activation
Design Overview: Shared Can Logistics

- We plan on sharing our canister space with Hobart Williams Smith Colleges.

- Their mission is to Measure muon flux at different levels in the atmosphere, Model how the Earth’s magnetic field changes with respect to altitude, and get local students engaged in STEM fields, and have them help to build their payload.

We currently communicate through email/text and plan on collaborating designs through solidworks.

A mid mounting plate will be used and we have no preference of orientation.
Project Management
Emily Certain
Management: Org Chart

Emily Certain
- Project Manager

Sebastian Reger
- Deputy Project Manager

Jeff Reynolds
- FSU Lead

Jeffrey Moe
- WVU Lead

Ronald Willis
- BRCTC Lead

TBD
- PAXC Lead
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<td>Conceptual Design Review Teleconference</td>
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<td>Earnest Deposit Due</td>
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<td>Electrical Design Requirements Document Fabrication</td>
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<td>10/30-11/3/17</td>
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Management: Monetary Budget

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Total (no margin): $8440.00

Total (w/ margin): $10,745.00
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Main Concerns

- Ensuring that all teams address all of the deliverables required by each design review

- The PAXC Team is rather large and geographically challenged so I’m worried about how the project will progress

- We’ve only received a team photo from 2 teams are not yet able to formulate the team collage
Conclusion

Overall, the mission of the Space Flight Design Challenge is to collaborate with institutions to foster innovative advancements in space payload design.

Within the next week we anticipate advancements in both our mechanical and electrical designs for the overall half canister and will need to do further investigation with the payloads involving ground stations through amateur radio operations.

The next steps will be to make subsystem and lower level requirements and to come up with a rough-draft design with trade studies for PDR