University of Delaware
ROCKSAT-C CDR

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RockSat-C 2018 CDR
CDR Presentation Contents

● Section 1: Mission Overview
  ○ Mission Statement
  ○ Theory and Concepts
  ○ Minimum Success Criteria
  ○ Mission Requirements (detailed)
  ○ Expected Results
  ○ Concept of Operations

● Section 2: System Overview
  ○ Subsystem Definitions
  ○ System Level Block Diagrams
  ○ Critical Interfaces (ICDs)
  ○ Ports (if applicable)
  ○ User Guide Compliance
  ○ Sharing Logistics
CDR Presentation Contents

● Section 3: Subsystem Design
  ○ Subsystem Inertial Navigation Board (INS)
    ■ INS Block Diagram
    ■ INS Key Trade Studies
    ■ Subsystem Risks/Mitigation
  ○ Subsystem Device Under Test (DUT)
    ■ DUT Block Diagram
    ■ DUT Key Trade Studies
    ■ Subsystem Risk/Mitigation
  ○ Subsystem Power/Micropayload Board

● Section 4: Prototyping Plan
  ○ Item “INS” to be Prototyped
  ○ Item “DUT” to be prototyped
  ○ Item “Power/Micropayload” to be prototyped
CDR Presentation Contents

● Section 5: Project Management Plan
  ○ Organization Chart
  ○ Schedule
  ○ Budget
  ○ Team Contact Matrix
  ○ Team Availability Matrix
Mission Overview
Mission Statement

Demonstrate the durability and test performance characteristics of a graphene-silicon based optical chip under launch conditions. Additionally, construct and test a reusable inertial navigation system and platform for future ROCKSAT-C missions. Provide a platform for other students to include micropayloads.
Mission Overview

● Primary payload:
  ○ Test silicon-graphene photonic devices for mechanical/electrical reliability under launch conditions
  ○ Parallel testing being done on radiation resistance of chips
  ○ Many potential applications

● Secondary payloads:
  ○ Inertial Navigation System - Track position of satellite without use of GPS + outside trackers
    ■ Need for systems to track position without outside references
  ○ Reusable payload platform
    ■ Power buses + vital sensors (3 axis accelerometer + gyroscope)
    ■ Space for micropayloads designed by other students
Mission Overview

● Project Requirements
  ○ Must be able to accurately measure µA-level currents
  ○ Must be able to track payload position with minimal drift
  ○ Need system to store and offload data
  ○ Must be able to support several micropayloads and their power/data/processing requirements

● Minimum success criteria
  ○ Alternatively: identify time + forces on payload at time of failure

● Comprehensive Success Criteria
  ○ Recover the IV curve data and the intact photonic device
  ○ Measure forces, acceleration, orientation of payload
  ○ Return all collected data to creators of the micropayloads
Mission Overview

- Mission Timeline:
  - Systems must record data before, during and after launch and flight
    - Will simultaneously be measuring forces/acceleration on payload
  - Need to see if forces on payload at launch time cause devices to fail
    - Turning on after liftoff means we may not have any usable data in case of failure at launch
  - Therefore, systems should be powered on and be recording around t-3 minutes to launch
    - Potentially could be closer to launch, depending on how long boot time for systems is
De-Scopes and Off-Ramps

Potential Issues:

● May not be able to package photonic devices by launch
  ○ Will just test device ability to survive flight and only test on ground

● May not have INS board working by flight
  ○ Have backup INS system to use

● May not enough power to supply to micropayloads
  ○ Can increase amount of power storage on board, or drop micropayloads

● May not have any micropayloads ready in time
  ○ Micropayload stack can be removed from the final design
System Overview
System Overview

● Primary Payload (DUTB) Functional Requirements
  ○ System:
    ■ Shall measure the IV curves for silicon-graphene photonic devices
    ■ Shall record save recorded data to storage
    ■ Shall be operational for entire flight

● Design Requirements
  ○ System:
    ■ Shall include several devices operating in parallel (target: 6)
      ● Devices shall operate at different fixed points on IV curve
    ■ Shall amplify μA currents using TIA
    ■ Shall store data in real time in case of power failure
  ○ Will test system to verify operating characteristics, power consumption
System Overview

● Secondary Payload (INS) Functional Requirements
  ○ System:
    ■ Shall monitor forces/acceleration of payload throughout flight
    ■ Shall calculate position and trajectory of payload
    ■ Shall be operational for entire flight

● Design Requirements
  ○ System:
    ■ Shall use accelerometers capable of measuring +/- 25 G (10DOF)
      • choice of accelerometer TBD
    ■ Shall amplify μA currents using TIA
    ■ Shall carry large enough batteries to power system for several hours
    ■ Shall store data in real time in case of power failure
  ○ Will test and benchmark system before launch
System Overview

● Power Board and Micropayloads
  ○ System:
    ■ Shall provide regulated power supply to all other subsystems
    ■ Shall be controlled by the WFF master switch
    ■ Shall provide different voltage levels sources (+5V, +3.3V, etc.)
    ■ Shall provide space, power, and computation for micropayloads to the seated

● Design Requirements
  ○ System:
    ■ Shall have multiple 9V batteries as a power source
    ■ Shall have power busses that deliver power to other systems
    ■ Shall give micropayloads a fixed build area and power pins
    ■ Shall provide each micropayload with an Arduino Pro for computation needs
System Overview

● Changes Since PDR
  ○ None of our work so far has indicated that we need to change our design
System Level Block Diagram

- Lines with lightning bolt are power lines
  - Max voltage in system is +9V
- Line between the microcontroller and DUT provides power and data transfer
- Line between the microcontroller and INS provides power and data transfer
- Besides power lines, each board operates independently of one another
System Level Mechanical Drawing
Subsystem Design
Inertial Navigation System Board
Physical Model - INS
Software Flow Diagram - INS

1. Start
2. Initialize accelerometer
3. Initialize SD card
4. Read acceleration (x, y, z)
5. Write data to SD card
6. Is external switch triggered?
   - Yes: End
   - No: Read pitch, roll, and heading

7. Process continues...
Device Under Test Board
Electrical Schematic - Device Under Test Board
Electrical Schematic - Device Under Test Board
Physical Model - DUTB
Software Overview - DUTB

- Similar to INS sensor system
- Initialize, than sample and write to SD card
  - Loop until device retrieved
Power/Micropayload Board

Figure 1: 1.SYS.1 Activation Diagram

Figure 2: Power and M.P. boards
Electrical Schematic - Power Board

VCC Power Supply (5V and 3.3V)
Electrical Schematic - Power Board

DUT Bias Power Supply
Electrical Schematic - Power Board

Power Board Combined Schematic
Micropayload Stack

Top Board (white)

Arduino Pro

Storage

Micropayload occupies top board (and potentially free space on bottom board)

Bottom Board (red)

+5V

TX/RX
Physical Model - Power Board
User’s Guide Compliance

- **Predicted weight**: 5 lbs.
  - Will need to increase weight with plates/additional batteries
- **Size**:
  - No large components on DUTB or INS boards
- **CG** will be within 1 in. x 1 in. 1 in. of center of canister
- **Will need to coordinate with canister partner to verify CG**
  - Still need canister partner
  - No preference to top or bottom
- **Will not need port**
- **Will be well under 1A current limit for wires**
# Microcontroller Trade Study

<table>
<thead>
<tr>
<th>Microcontroller</th>
<th>Teensy 3.5</th>
<th>Teensy 3.2</th>
<th>Raspberry Pi 0</th>
<th>Arduino Pro</th>
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<tr>
<td>Cost</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>10</td>
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<tr>
<td>Availability</td>
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<td>10</td>
<td>5</td>
<td>7</td>
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Microcontroller Trade Study Notes

- Payload INS system based off of existing system that uses a Teensy 3.2
- Teensy 3.5 provides data storage, increased processing capabilities
- Can use C for programming languages
- Use of Arduino Pro with micropayloads will maximize the space available for other components
## Accelerometer Trade Study

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<th>10 DOF</th>
<th>LIS331</th>
<th>ADXL377</th>
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<td>Availability</td>
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<td>Force Measuring Capability</td>
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<tr>
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<td>5</td>
<td>2</td>
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<tr>
<td>Ease of Integration</td>
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<td>10</td>
<td>5</td>
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## DUT: Trade Studies

<table>
<thead>
<tr>
<th>Microcontroller</th>
<th>Teensy 3.5</th>
<th>Teensy 3.2</th>
<th>Raspberry Pi 0</th>
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<tr>
<td><strong>Cost</strong></td>
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<tr>
<td><strong>Familiarity</strong></td>
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<tr>
<td><strong>Ease of Integration</strong></td>
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<td>10</td>
<td>5</td>
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</table>
Risk Assessment

- **Power Failure**
  - Results in no data and no experiments performed

- **Electronics break due to G-forces**
  - Paint shaker tests may not be adequate enough
  - Result in lost data and/or some experiments not being performed
  - Wire bonds between package + photonic chip especially vulnerable

- **IV curves not known beforehand**
  - Potential issues with wire bonding and/or measurement devices
  - Can still acquire data, but will not have anything to compare it to
Risk Assessment

- Power failure is not very likely, but results in experiment failure
- Electronics breaking still gives some results, but is not ideal
- Not knowing IV curves is unlikely and does not cause significant problems
- Overall, risks lie in an acceptable range
Weight Budget

- Estimate that each board will be similar in weight
- Consists of entirely solid state components
- Significantly underweight
- Will add ballast of lead weights

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<tr>
<th>Subsystem</th>
<th>Mass (g)</th>
<th>Mass (lb)</th>
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<tbody>
<tr>
<td>Power Board</td>
<td>180 (estimate)</td>
<td>0.397 (estimate)</td>
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<tr>
<td>INS Board</td>
<td>180</td>
<td>0.397</td>
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<tr>
<td>DUBT Board</td>
<td>180 (estimate)</td>
<td>0.397 (estimate)</td>
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<tr>
<td>Batteries</td>
<td>90</td>
<td>0.198</td>
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<tr>
<td><strong>Total</strong></td>
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<tr>
<td><strong>Over/Under</strong></td>
<td><strong>1637</strong></td>
<td><strong>3.61</strong></td>
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## Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage</th>
<th>Max Current</th>
<th>Time on (min)</th>
<th>mAh</th>
<th>Power</th>
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<tbody>
<tr>
<td>Micropayloads</td>
<td>3.3V - 5V</td>
<td>100 uA * 3 payloads</td>
<td>180</td>
<td>0.9</td>
<td>1.5 mW</td>
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<tr>
<td>DUT</td>
<td>5V</td>
<td>100 mA</td>
<td>180</td>
<td>300</td>
<td>500 mW</td>
</tr>
<tr>
<td>INS</td>
<td>5V</td>
<td>50 mA</td>
<td>180</td>
<td>150</td>
<td>250 mW</td>
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All subsystems will remain on for the entire flight and recovery process.
Test/Prototyping Plan
Test/Prototyping Plan

- **INS Prototyping Plan**
  - Test INS to see if works
    - If not we will gradually debug it before our next presentation

- **DUT Prototyping Plan**
  - Get Wire Bonding done for the photonic chip
    - Measure I-V curves

- **Micropayload Prototyping Plan**
  - Create standard template for micropayload designers to use
    - Verify Arduino Pro setup works
  - Completed micropayloads will be tested and verified independently by our team before they are integrated into the system

- **Vibration testing will be done with a paint shaker**
Manufacturing Plan
Manufacturing

- Create PCBs in CAD send out for manufacture
  - CAD design will take two to three days
- Send out PCBs to be manufactured
  - Manufacture will take two weeks
- Hand solder the rest of the components
  - This will take one to two days
Software Elements

- Modify INS code from previous project
- Create code for DUTB
Testing Plan
Testing

- PCBs to be fabricated during spring
  - Design of PCBs will take 2-3 days
  - Fabrication will take 2 weeks
  - Soldering will take 1-2 days
- Test micropayloads align with ROCKSAT requirements
  - No interference and proper power usage
- Time how long entire system can stay running on a fresh battery
- Test INS recording and accuracy on the ground
- Record DUT IV curves before launch
- Vibrational testing at UD and at WFF
Project Management Plan
Team Organization

● Jingcheng Lu - Student Project Team Leader - ariclu@udel.edu
  ○ Co-designer of the DUT board
  ○ Main contact with ROCKSAT-C program
● Ryan Beneck - Team Member - rbeneck@udel.edu
  ○ Designer of the INS board
● Benjamin Steenkamer - Team Member - bsteen@udel.edu
  ○ Designer of the power/micropayload board
● Anton Vasilyev - Team Member - vasilyev@udel.edu
  ○ Co-designer of the DUT board
● Dr. Chase Cotton - Faculty Supervisor - ccotton@udel.edu
Team and Project Schedule

- Some flexibility with meeting times, especially on Fridays

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
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RockSat-C 2018
CDR

<table>
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<tr>
<th>Date</th>
<th>Event</th>
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<tr>
<td>10/31/2017</td>
<td>Preliminary Design Review (CoGSC)</td>
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<td>11/5/2017</td>
<td>Fall Midterm Report (UDEL)</td>
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<td>11/30/2017</td>
<td>Schematics + Mechanical Diagrams Finished</td>
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<td>12/4-12/8/2017</td>
<td>Critical Design Review (CoGSC)</td>
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<tr>
<td>12/5 -12/7/2017</td>
<td>Fall Final Presentation (UDEL)</td>
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<tr>
<td>12/10/2017</td>
<td>Fall Final Report and Software (UDEL)</td>
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<tr>
<td>12/5/2017</td>
<td>Begin building subsystems (continue over winter break)</td>
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<tr>
<td>12/5/2017</td>
<td>Finalize micro-payload selection</td>
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<tr>
<td>1/22-1/26/2018</td>
<td>Subsystem Testing Review (CoGSC)</td>
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<tr>
<td>3/10/2018</td>
<td>Finish Building Subsystems + Integration</td>
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<tr>
<td>3/30/2018</td>
<td>Vibration Testing</td>
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<tr>
<td>4/9/2018</td>
<td>Begin integrating payload into Launch Canister</td>
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<tr>
<td>6/13/2018</td>
<td>Travel to WFF for pre-launch testing</td>
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<tr>
<td>6/21/18</td>
<td>Launch Day</td>
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Budget

● Currently seeking funding from the Delaware Space Consortium
  ○ Help pay for bulk of program fees

● Looking for another University to share part of our canister with
  ○ Partner has been found; waiting for communication

● University of Delaware ECE department will cover cost of build materials
  ○ Will reuse components from previous projects to reduce the cost
  ○ Cost of new components expected to be minimal
Conclusion

● Future Plans
  ○ Build/complete prototypes
  ○ Test INS code
  ○ Collaborate with CVORG to complete wire bonding of the photonic chip to a platform
    ■ Measure I-V curves
  ○ Finding students willing to design micropayloads
  ○ Have PCBs designed and fabricated