Stevens Institute of Technology

sponsored by

NJ Space Grant Consortium

Conceptual Design Review
Agenda

Science Subsystems:

- 3D Printing in Microgravity
  - Theory & Concepts
  - Mission Requirements
  - Design Overview
- Fiber Optic Gyroscope
  - Theory & Concepts
  - Mission Requirements
  - Design Overview

- Boundary Layer Pressure Sensor
  - Theory & Concepts
  - Mission Requirements
  - Design Overview
- Self-Healing Epoxy
  - Theory & Concepts
  - Mission Requirements
  - Design Overview
Overall

- Concept of Operations
- Functional Block Diagrams
- Payload Layout
- User’s Guide Compliance
- Shared Can Logistics
- Team Organization
- Schedule
- Budget
- Mentors (Faculty, industry)
- Team Contact Matrix
- Team Availability Matrix
3D Printing In Microgravity

Mission Statement:
The goal of this payload is to test the effects of high G’s and microgravity on 3D prints.
Theory and Concepts

• We theorize that varying G-forces will affect layer lamination (i.e. adhesion and compression), and rocket vibration will cause a reduction in resolution.

• 3D printers currently experience problems in resolution and layer adhesion, and require well-calibrated conditions to function well. This experiment will attempt to view print results under extreme mechanical conditions that would typically destroy prints.
• In 2015, Virginia Tech designed a delta 3D printer for RockSat-X to test the viability of additive manufacturing in microgravity. They were successful in printing their school’s logo.

• M3D LLC released The Micro, a 3D printer smaller than 8” in every direction, this previous summer.

• Evaluating both of these designs, we hope to build upon their developments to make an ideal machine.
Expected Results

• We expect to see varying compressions and therefore thicknesses between the many layers along the z-axis due to changes in acceleration of the rocket.

• Vibrations of the rocket will also likely cause imperfections along the x and y axes, characterized by random, jagged artifacts.

• In an ideal environment, z layers will be of equal thickness with no artifacts across the x-y plane.
Mission Requirements

• Objective: Evaluate the effects of various extremes of acceleration on 3D printing.

• System Requirements:
  – The 3D printer must be rugged enough to withstand high G’s, rotations, and vibrations.
  – The sample print must be completed in a short time span, across multiple G’s.
  – The print must start and stop at preset times in order to sync layers with acceleration data.
Minimum Success Criteria

Completing at least 40% of a print (even a partial print will supply data on where failure occurred mid-flight).
Design Overview

• Structure: The printer will be a 3-Directional Cartesian model
  – Belt & lead screw driven
  – Within 4” in vertical direction (Z-axis)
  – Within 6” in each horizontal direction (xy-plane)

• Dependencies: Temperature sensor, 3 motors (type to be determined), maximum of 12V power supply throughout flight
Design Overview

XY-Plane Actuation

Extruder Location

Build Plate

Z-Axis Actuation

Frame
1 Axis Sagnac FOG (Fiber Optic Gyroscope)

To build a one axis fiber optic gyroscope that can effectively measure the rotational motion of the system. Our design could be used for an effective gyroscope for space travel.
Theory and Concepts

• Developing and designing a 1 axis fiber optic gyroscope

• The gyroscope will work according to the Sagnac principle

• We will test the gyroscope at the several stages of the space flight, including launch and apogee
Developing and designing a 1 axis fiber optic gyroscope
The gyroscope will work according to the Sagnac principle
We will test the gyroscope at the several stages of the space flight, including launch and apogee
How does the rocket move? How can we describe the motion of the rocket?

We want to make an effective and stable gyroscope that can measure the rotational motion/velocity of the rocket.

Can we build a cost effective FO gyroscope that can still be effective in measuring these parameters?

Expected spin

1.3Hz at Terrier Burnout
5.6Hz at Orion Burnout
Design Overview

FOG plate for fiber optic gyroscope experiment

Fiber optic will most likely be wound around the plate

Estimated dimensions: 5.64” x 5.64 x .62”

The use of epoxy may also be necessary for our gyroscope
Mission Requirements

- 10% margin of error between FOG and simultaneous turntable testing
- FOG survives flight without loss of function
The diode/light source would emit a signal of certain energy/voltage. The signal would be split by the coupler into 2 identical signals. Both signals would travel around the spool of fiber optic and meet/interfere in the spool. Both signals would then travel back out the way they came in. The signal would come out through the coupler, half would dissipate in the light source but the other half would be picked up by the sensor.
The goal of this project is to measure High-Speed Boundary Layer Transitions from laminar to turbulent pressure waves using a piezoresistive and piezoelectric pressure sensor combination mounted in a custom window on the skin of the rocket.
Theory and Concepts

- High-Speed Boundary Layer Transition
  - Laminar -> Unstable -> Turbulent
- Laminar to Turbulent transition in High-Speed Boundary layers helps to predict and control heat transfer, skin friction, and other boundary-layer properties. By collecting this data we can better understand the mechanisms leading to transition.
- This data is valuable because it is difficult to simulate these flows in wind-tunnel due to high levels of noise.
- This data can then be extrapolated further to other spacecraft.
Theory and Concepts

• Considerable research has been conducted in Boundary Layer Transitions.
  – However data from actual launches are a valuable resource in further understanding Boundary Layer Transitions

• For this project, primary sources of research include:
  – Boundary Layer Transition in High-Speed flows due to roughness
    • Prahladh S. Iyer, Suman Muppidi & Krishnan Mahesh
  – Flight Data for Boundary-Layer Transition at Hypersonic and Supersonic Speeds
    • Steven P. Schneider

• Research has been conducted into boundary layer transition to predict performance.
• Record and measure the transition of the boundary layer from laminar to turbulent waves using a combination of a piezoresistive and piezoelectric pressure sensors.

• In addition, an accelerometer, gyroscope, and thermocouple will be used to support and adjust measurements of pressure sensors.
Mission Requirements

- The pressure sensors must be exposed to atmosphere flush with the skin of the rocket. A window space will be required to facilitate this design.
- Data must be recorded during the period of interest when the rocket is approaching and travelling at approximately Mach 4. Ideally, the window from launch to 130-200 seconds into flight will be recorded.
- Mission requires useable, high-fidelity data to be available upon rocket recovery. Current goals for sample rate and resolution are 2MHz and 16-bits, respectively.
Mission Requirements

• Accelerometer and Gyroscope should measure consistent data and vibrations should be minimized.
  – The sampling rate should be at least 1MHz
• The thermocouple should measure consistent data at a rate of 500KHz.
Expected Results

- Minimum success criteria:
  - Successfully sample Boundary layer flow at any sample rate and resolution.
- Expect to record and measure instability waves on the boundary layer of the rocket at the given resolution and sampling rate.
- Further research can be conducted with both data collected and NASA’s own post flight data.
  - Research boundary layer transition estimation methods.
Design Overview

• Data Collection will occur from $t = 0$ to $t = 130s$ during burns. This period will include a moment where velocity is at Mach 4.

• Our data relies heavily on a velocity with high enough Mach number.
Design Overview

• Two types of high-frequency pressure sensors:
  – Piezoresistive
    • Low frequency pressure waves
    • Better static readings
  – Piezoelectric
    • High frequency pressure waves
    • Better dynamic readings.

• Full Picture Sensors:
  – Use of an Accelerometer, Gyroscope and barometer to get better picture of the state of the rocket.

• Thermocouple
  – To supplement the data recorded by the pressure sensors and adjust the data accordingly.
Design Overview

● Pressure sensors are to be sampled at a 2MHz sample rate with a resolution of 16 bits.
  ○ This will require an A to D convertor that can translate the data at this rate without loss.

● A FPGA (Field Programmable Gate Array) will manage the data output of all the sensors. It will timestamp the data using a Real Time Clock then transfer the data into storage.
  ○ The FPGA can be programmed to process the data in real-time to effectively combine all sensor readings at a certain moment in time.

● Multiple SDHC cards will be used for storage
  ○ The FPGA will use a SPI interface for communication to SD Cards.
Design Overview

● The pressure sensors must be mounted flush with the skin of the rocket with an appropriate sized opening.
  ○ The skin of the rocket must be pierced and must be airtight to conform to design requirements and prevent water from entering the modules on landing.
  ○ Proper mounts for the sensors are required to be designed and machined to accommodate the various pressure and thermocouple designs. (Threaded vs. Glued)
● The accelerometer and gyroscope mounts have to be designed to not allow any motion.
Design Overview

• FPGA and Storage
  – 5V - 12V, 200mA
• ADC
  – 5V - 12V, 200mA
• Sensors
  – Pressure Sensors
    • 5V - 12V, 200mA
  – Accelerometer and Gyroscope
    • 5V - 12V, 200mA
  – Thermocouple
    • 5V - 12V, 200mA
Design Overview

• Add sketch later
• 2 Electronic boards
  – 1 for FPGA, ADC and SD Card, 1 for Accelerometer and gyroscope
• 1 Plate for all electronics
• A window that supports a flush mount for the pressure sensors and a mount touching the skin for the thermocouple.
• Brackets to thread and glue pressure sensor and thermocouple on window of rocket.
Self Healing Epoxy

To gather data to validate a design for a cost effective self healing membrane that can be used in spaceflight
Overall Operations

- Concept of Operations
- Functional Block Diagrams
- Payload Layout
- RockSat-C 2016 User’s Guide Compliance
- Shared Can Logistics (if applicable)
- Team Organization
- Schedule
- Budget
- Mentors (Faculty, industry)
- Team Contact Matrix
- Team Availability Matrix
Theory and Concepts

• 2 layer epoxy self-healing skin
• Testing the curing rate of epoxy skin when punctured
• Use a needle attached to a solenoid to puncture skin
• Film curing process with 1080p camera and LED to illuminate testing chamber
• Similar “self healing” experiments have been performed on Earth but not in microgravity
Mission Requirements

• 60 Second Epoxy

• Test the effects “60 second” or other fast curing epoxy

• Experiment contained in sealed box to prevent epoxy leakage

• The ability of the skin to seal the puncture inflicted on it will determine the success/failure of the experiment
Expected Results

• 2 part epoxy trends
  – Once the layer separating the 2 parts of the epoxy is punctured the curing agent and epoxy resin will come into contact with one another
  – Distribution and curing of epoxy will continue until the exposed area has been sealed off, and the rest of the epoxy resin and curing agent are no longer in direct contact with one another
  – Hardened epoxy will be left where a hole once was
Design Overview

- Approximately 3” x 3” x 3” cube to test epoxy skin in
- Raspberry Pi is approximately 3.5” long by 2.5” wide by .75” high
Design Overview

Key:
Blue Arrow = Data
Red Arrow = Power

Power Source Battery

LED

Raspberry PI

SD Card

Camera

Solenoid

Punctures

Epoxy Skin
Design Overview

• Data will be saved to the on-board SD card.

• Pi handles data acquisition, writing to SD card, and signaling LED and solenoid.
Concept of Operations

T = -10 min
All subsystems activate
3D printer warmup

T = +5 sec
- G switch triggered
- 3D printer begin printing sample
- Self-healing epoxy punctured

T = +5 mins
- 3D printer stop print

T = +130 s
Burn ends. Boundary - Layer data collection ends

T = -10 min
All subsystems activate
3D printer warmup

T = 0 min
Payload Layout

Sensors are mounted through and flush with the skin of the rocket. The sensors can be threaded through a bracket holding them and the thermocouple to the window.

Plastic plate mounted on standoffs that limit movement. Sensors mounted on vibration dampeners.

Wires to window with mounting for pressure sensors and thermocouple. Pressure sensors require an airtight mounting hole.
RockSat-C User’s Guide Compliance

- Predicted Mass:
- Predicted Volume: Half a canister
- Activation: T-5mins
- Access to external window for pressure sensors
Shared Can Logistics

- Will share can
- If Mitchell is not participating, no preference for pairing
Organization Chart

Professor Joseph Miles

Andrew Isherwood
Payload Integration / Overall Design

Miklos Nyary
Lead Design Reviews

Ethan Hayon
S/W Integration

Roger Kleinmann
3D Printer Project Manager

Jonathan Eugenio
FOG Project Manager

Arun Arulothi
Skin Flow Sensor Project Manager

Daniel Place
Self-Healing Epoxy

Matt Lagarenne

Kenneth Barth

Chris Blackwood

Maria Lopez Cavestany

Nathan Tahbaz

Zeyi Tang

Vincent Persky

Salma Alshafie

Sankee Maringanti

Anthony Lanza

Doug Sholander

Scott Maslin

Nick Osborne

Abe Edens

John Anticev

Robert Fea

Vijay Raja

STEVENS INSTITUTE of TECHNOLOGY
Schedule

• End of October: Final conceptual design. Possibly eliminate science subsystems if necessary.

• End of November: Finish detail design

• End of December: Final detailed estimates

• End of January: Complete procurement and begin construction
Budget

- 3D Printer: $400
- Boundary Layer Pressure Sensor:
  - Sensors:
    - Pressure Sensors: $500
    - Accelerometer and Gyroscope: $100
    - Thermocouple: $50
  - Computation
    - ADC: $100
    - FPGA: $100
- Brackets and Mounting components
  - Total Cost: $50
Team Mentors

- Professor Miles – All Science Subsystems
- Professor Parziale – Boundary Layer Pressure Sensor
- Professor Search – Fiber Optic Gyroscope
- Professor Strauf – Fiber Optic Gyroscope
<table>
<thead>
<tr>
<th>Name</th>
<th>Email Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethan Hayon</td>
<td><a href="mailto:ehayon@stevens.edu">ehayon@stevens.edu</a></td>
</tr>
<tr>
<td>Andrew Isherwood</td>
<td><a href="mailto:isherwood.andrew@gmail.com">isherwood.andrew@gmail.com</a></td>
</tr>
<tr>
<td>Miklos Nyary</td>
<td><a href="mailto:miklos.nyary@gmail.com">miklos.nyary@gmail.com</a></td>
</tr>
<tr>
<td>Matt Lagarenne</td>
<td><a href="mailto:mlagaren@stevens.edu">mlagaren@stevens.edu</a></td>
</tr>
<tr>
<td>Nathan Tahbaz</td>
<td><a href="mailto:ntahbaz@stevens.edu">ntahbaz@stevens.edu</a></td>
</tr>
<tr>
<td>Nick Osborne</td>
<td><a href="mailto:nosborne@stevens.edu">nosborne@stevens.edu</a></td>
</tr>
<tr>
<td>Abe Edens</td>
<td><a href="mailto:aedens@stevens.edu">aedens@stevens.edu</a></td>
</tr>
<tr>
<td>Roger Kleinmann</td>
<td><a href="mailto:rkleinma@stevens.edu">rkleinma@stevens.edu</a></td>
</tr>
<tr>
<td>Zeyi Tang</td>
<td><a href="mailto:ztang4@stevens.edu">ztang4@stevens.edu</a></td>
</tr>
<tr>
<td>Daniel Place</td>
<td><a href="mailto:dplace1@stevens.edu">dplace1@stevens.edu</a></td>
</tr>
<tr>
<td>Salma Alshafie</td>
<td><a href="mailto:salshafi@stevens.edu">salshafi@stevens.edu</a></td>
</tr>
<tr>
<td>Rachael Bramlage</td>
<td><a href="mailto:rbramlag@stevens.edu">rbramlag@stevens.edu</a></td>
</tr>
<tr>
<td>Scott Maslin</td>
<td><a href="mailto:smaslin@stevens.edun">smaslin@stevens.edun</a></td>
</tr>
<tr>
<td>Maria Lopez Cavestany</td>
<td><a href="mailto:mlopezca@stevens.edu">mlopezca@stevens.edu</a></td>
</tr>
<tr>
<td>Akshay Sampath</td>
<td><a href="mailto:asampat1@stevens.edu">asampat1@stevens.edu</a></td>
</tr>
<tr>
<td>Vijay Raja</td>
<td><a href="mailto:vrajathi@stevens.edu">vrajathi@stevens.edu</a>&gt;</td>
</tr>
<tr>
<td>Kenneth Barthman</td>
<td><a href="mailto:kbarthma@stevens.edu">kbarthma@stevens.edu</a></td>
</tr>
<tr>
<td>Jonathan Eugenio</td>
<td><a href="mailto:jeugenio@stevens.edu">jeugenio@stevens.edu</a></td>
</tr>
<tr>
<td>Anthoney Lanza</td>
<td><a href="mailto:alanza1@stevens.edu">alanza1@stevens.edu</a></td>
</tr>
<tr>
<td>Sankeerthana Maringanti</td>
<td><a href="mailto:smaring1@stevens.edu">smaring1@stevens.edu</a>&gt;</td>
</tr>
<tr>
<td>Arun Aruliothi</td>
<td><a href="mailto:aaruljot@stevens.edu">aaruljot@stevens.edu</a></td>
</tr>
<tr>
<td>Chris Blackwood</td>
<td><a href="mailto:cblackwo@stevens.edu">cblackwo@stevens.edu</a></td>
</tr>
<tr>
<td>Robert Fea</td>
<td><a href="mailto:rfea@stevens.edu">rfea@stevens.edu</a></td>
</tr>
<tr>
<td>Vincent Persky</td>
<td><a href="mailto:vpersky@stevens.edu">vpersky@stevens.edu</a></td>
</tr>
<tr>
<td>Doug Sholander</td>
<td><a href="mailto:dsholander@stevens.edu">dsholander@stevens.edu</a></td>
</tr>
<tr>
<td>John Anticev</td>
<td><a href="mailto:janticev@stevens.edu">janticev@stevens.edu</a></td>
</tr>
<tr>
<td>Prof. Nick Parziale</td>
<td><a href="mailto:Nick.Parziale@stevens.edu">Nick.Parziale@stevens.edu</a></td>
</tr>
<tr>
<td>Prof. Joseph S. Miles</td>
<td><a href="mailto:jmiles@stevens.edu">jmiles@stevens.edu</a></td>
</tr>
<tr>
<td>Time</td>
<td>Monday</td>
</tr>
<tr>
<td>------------</td>
<td>--------</td>
</tr>
<tr>
<td>7:00 AM</td>
<td>No</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>No</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>No</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>No</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>No</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>No</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>No</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>No</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>No</td>
</tr>
<tr>
<td>4:00:00 PM (6PM EST)</td>
<td>Fifth</td>
</tr>
<tr>
<td>5:00:00 PM (7PM EST)</td>
<td>First</td>
</tr>
</tbody>
</table>
Conclusion

• Lots of experimental subsystems. Might need to eliminate experiments that prove not viable

• Plenty of team members

• Woo, RockSAT