BRICSat-P
Ballastically Reinforced Communications Satellite
WHAT IS A CUBESAT?

- Miniaturized satellites classified according to height (10-30 cm)
- Purpose is to perform small spacecraft experiments.
- Use has increased due to relatively low cost
CubeSat missions are becoming more important

Missions are reliant on launch vehicle locations

Limited control on the CubeSat’s orbital altitude

Need better attitude control systems

Feasible propulsion system is needed to increase mission capability
### PAST MICROPROPULSION SYSTEMS

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Nominal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific impulse (sec)</td>
<td>220</td>
</tr>
<tr>
<td>Thrust (N)</td>
<td>1</td>
</tr>
<tr>
<td>Thruster Mass with Valve (g)</td>
<td>290</td>
</tr>
<tr>
<td>Propellant</td>
<td>Hydrazine ($N_2H_4$)</td>
</tr>
<tr>
<td>Accumulated Burn Life (hours)</td>
<td>50</td>
</tr>
</tbody>
</table>

1 N Hydrazine Thruster

kenji.dinelli@gmail.com
ALTERNATIVE OPTION

- Electric Propulsion (EP) provides an option
  - Specific impulse values up to 5,000 seconds
  - Thrust duration lasts from weeks to years
  - Xenon and Teflon are common propellants
- Problems:
  - Require large amounts of power (>~300 W)
  - Take up about half of payload volume and mass of 1U to 3U CubeSats
# MICRO-CATHODE ARC THRUSTERS

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Nominal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific impulse (sec)</td>
<td>3000</td>
</tr>
<tr>
<td>Thrust (N)</td>
<td>1µN</td>
</tr>
<tr>
<td>Thruster System Mass (g)</td>
<td>200</td>
</tr>
<tr>
<td>Propellant</td>
<td>Titanium cathode</td>
</tr>
<tr>
<td>Average Power (W)</td>
<td>0.1</td>
</tr>
<tr>
<td>Thruster System Volume (cm³)</td>
<td>200</td>
</tr>
<tr>
<td>Delta-V (for 4 kg satellite) (m/s)</td>
<td>300</td>
</tr>
</tbody>
</table>

Micro-cathode Thruster Heads
MISSION AND OBJECTIVES

• Mission: Collaborate with The George Washington University to successfully demonstrate an electric propulsion system in orbit for application to CubeSat missions

• Primary objectives:
  – Integrate a miniature size propulsion system into a 1.5U CubeSat
  – Perform three maneuvers in space: de-tumbling, pointing control, and delta-V

• Secondary objective is to expand APRS network
CONCEPT OF OPERATIONS

- Will fire up to four thrusters
- Perform three key maneuvers:
  - Initial De-tumbling
  - Controlled spin about two axes
  - Delta-V Operation
- Gyro and magnetometer used for measurements
MISSION PLAN

BRICSat-P Mission Flow Chart
**SUCCESS CRITERIA**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Attainable</th>
</tr>
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<tbody>
<tr>
<td>The thrusters can successfully fire.</td>
<td></td>
</tr>
<tr>
<td>BRICSat-P can de-tumble successfully</td>
<td></td>
</tr>
<tr>
<td>BRICSat-P can spin and de-spin in a stable manner.</td>
<td></td>
</tr>
<tr>
<td>Enough power is available to perform successful Delta-V maneuver.</td>
<td></td>
</tr>
<tr>
<td>The process can be repeated.</td>
<td></td>
</tr>
</tbody>
</table>
# Satellite Overview

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>1.5 U</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>1.9</td>
</tr>
<tr>
<td>Volume (cm³)</td>
<td>1500</td>
</tr>
<tr>
<td>Antenna Lengths (cm)</td>
<td>HF-182.88, VHF-48.26, UHF-15.24</td>
</tr>
<tr>
<td>Number of Thruster Systems</td>
<td>4</td>
</tr>
</tbody>
</table>
INTEGRATION AND MISSION ANALYSIS
USNA TEAM

kenji.dinelli@gmail.com
BRICSAT-P DESIGN PROGRESSION

• Place four thruster heads around center of mass
• Permanent magnet to stabilize CubeSat
• Intermediate Design:
  – Integrate four full thruster systems into BRICSat-P
  – Power unit changed from 1.5U to 1U
  – Thruster systems placed on y-axis plane

Initial Design with Thruster Placement
• MATLAB Simulink model
  – Simulate effects of aerodynamic drag, magnetic field, and gravity gradient torque
  – Permanent magnet de-tumbling analyzed
  – Incapable of de-tumbling spacecraft

Failed Magnetic Stabilization
• Use thrusters for attitude and rate control
  – Meets all of mission objectives
  – Fully characterize thruster system
• Two possible thruster configurations:
  – Staggered (2 thrusters on opposite face)
  – X-wing (all thrusters on same face)
THRUSTER CONFIGURATION

- Staggered configuration is only one orbit faster.
- X-wing configuration was chosen:
  - Less complicated mechanically
  - Makes delta-V scenario more feasible
  - Can de-tumble within 7 orbits
DE-TUMBLING GOALS

• Determine appropriate thruster configuration based on:
  – Initial Tumbling: 15 deg/sec
  – Target stability: +/- 1 deg/sec
• Determine the exact placement of thrusters
  – Fewest number of orbits to stabilize
• Determine duty cycle for thruster firing.
Satellite can successfully stabilize from initial tumbling in 7 orbits!

kenji.dinelli@gmail.com
ALTERING INITIAL CONDITIONS

Mass distribution and duty cycle affect thruster’s performance in rotation control mode.

kenji.dinelli@gmail.com
## FINAL DESIGN PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Configuration</td>
<td>X-wing</td>
</tr>
<tr>
<td>Placement</td>
<td>-Y Face</td>
</tr>
<tr>
<td>Separation (cm)</td>
<td>4.5</td>
</tr>
<tr>
<td>Duty Cycle (%)</td>
<td>50</td>
</tr>
<tr>
<td>Misalignment Tolerance</td>
<td>5 degrees</td>
</tr>
<tr>
<td></td>
<td>2 mm</td>
</tr>
</tbody>
</table>
RONATIONAL EXPERIMENT

• Target rotation rate of 6 rpm
• 22% duty cycle
  – 10 minutes to spin
  – 70 minutes of rest
  – 10 minutes to de-spin
• Camera will take pictures of thrusters
• Communications sent to USNA ground station
DELTA-V SCENARIO

• Magnetometer for CubeSat orientation
  – Based on magnetic field orientation
  – Can identify orientation in two axes planes
• Fire 4 thrusters along Earth’s magnetic field line
• Send pictures of thruster firing
• Modeled in MATLAB Simulink and STK
SOLAR POWER ESTIMATES

• Power Predictions:
  – Worst case scenario: 2.04W
  – Best Case: 4.34W
  – Orbit Average Power: 3.25W

• Thruster power requirements: 1 Watt
  – Power required is based on continuous firing

Triangular Advanced Solar Cells (TASC)
PAYLOAD DESIGN
GW TEAM
# THRUSTER SPECIFICATIONS

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<tr>
<td>Diameter (cm)</td>
<td>1</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>2.29</td>
</tr>
<tr>
<td>Backflux</td>
<td>None</td>
</tr>
<tr>
<td>Operational Life (years)</td>
<td>10</td>
</tr>
<tr>
<td>Total Impulse (N-sec)</td>
<td>120,000</td>
</tr>
<tr>
<td>Input Voltage (VDC)</td>
<td>5</td>
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</tbody>
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- Thruster Spark in Live Fire Test
- Final Thruster Boards

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FUTURE SCHEDULE

Final Testing → Delivery → Launch → Begin Operations → Collect and Analyze Data
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REFERENCES


• https://www.mpnl.seas.gwu.edu/index.php?option=com_content&view=article&id=49&catid=16&Itemid=124

REFERENCES

- http://cs.astrium.eads.net/sp/spacecraft-propulsion/hydrazine-thrusters/1n-thruster.html
QUESTIONS?

Christopher K Dinelli
kenji.dinelli@gmail.com

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