GW-Sat: GW’s First Satellite with Propulsive 3-Axis Stabilization

Jonathan Kolbeck, Michael Keidar
jkolbeck@gwu.edu
Agenda

• GW Involvement in Space
• Background Information
• Mission Goals
• CONOPS
• The Spacecraft
• μCAT System
• Propulsion Cluster I & II
• Primary Goal – Validation
• Secondary Goals – TEC
• CubeSat Development
• Challenges
GW Involvement in Space

Micro-Propulsion seen as key technology

- Micro-Cathode Arc Thruster developed at GW
- High demand for propulsion systems (Private industry & NASA Goddard/ Marshall)

- BRICSat-P: May 2015
- Canyval-X: Jan 2018
- BRICSat-2: 2H 2018
GW-Sat is part of the 2016 CubeSat Launch Initiative call for proposals

GW CubeSat lab founded in 2017

Funding status: approx. USD 100k

Goal: Establish a Satellite Program at GW to launch 1 CubeSat per year

Current equipment: 4x Linux based computers + 4 high-end computers with NVidia Quaddro GPUs for CAD modelling + simulation work

Working on securing a positive-pressure cleanroom

PDR completed in October 2017

CDR expected September 2018 + speed up ramp-up of operations
Primary Mission
• To validate the performance of GW’s Micro-Cathode Arc Thruster (µCAT) propulsion system

Secondary Goals
• Perform on-orbit testing and validation of a novel low-cost star tracker designed by students at MIT. The device is based on a new algorithm called TETRA
• GW-Sat will function as a store-forward communications node between a remote ground station from our partner university TEC from Costa Rica and GW’s ground station.
• Analyze the effect of the µCAT thruster’s plasma discharges on radio communications.

Overarching Goal: To train GW students with a real space mission
Launch to ISS

Release from Dispenser

Antenna deployment, Battery Charge, Health Check & Detumble

Solar Array Deployment

Mission:
- Test μCAT System (orbit raising, station-keeping)
- Verification of ADCS
- Imaging & Science Mission

End of Life:
- Propulsive de-orbiting
The Spacecraft

- BUS: 3 U @ 4 kg
- 12 Next-Gen µCAT thrusters
  - 8 for attitude control
  - 4 for main propulsion
- Launch early 2020
- Mission lifetime: 6+ months
- Vendors: various
μCAT System

Thruster Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing Material</td>
<td>PTFE</td>
</tr>
<tr>
<td>Propellant</td>
<td>Nickel</td>
</tr>
<tr>
<td>Size</td>
<td>Length: 27.6 mm</td>
</tr>
<tr>
<td></td>
<td>Width: 20.1 mm</td>
</tr>
<tr>
<td></td>
<td>Height: 14.0 mm</td>
</tr>
<tr>
<td>Required structural opening</td>
<td>Diameter: 14 mm</td>
</tr>
<tr>
<td>on side panel for plume</td>
<td></td>
</tr>
<tr>
<td>Total system mass</td>
<td>&lt; 200 g</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Approx. 1 W at 10 Hz</td>
</tr>
<tr>
<td>Firing rate</td>
<td>1-50 Hz</td>
</tr>
<tr>
<td>Trigger</td>
<td>5 V square wave signal</td>
</tr>
<tr>
<td>Charging Voltage</td>
<td>Approx. 15-25 V</td>
</tr>
</tbody>
</table>
Propulsion Cluster I

Bottom View

Side View
Propulsion Cluster II

BRICSat Thruster Architecture

GW-Sat Thruster Architecture
Primary Goal - Validation

• Spin up the spacecraft to approximately 10 degrees per second along the z-axis

• Perform station-keeping maneuvers for extended periods of time to delay the orbital decay.

• Demonstrate 3-axis stabilization and pointing capabilities of the 3 U CubeSat: Verification of the pointing accuracy will be done by comparing the image’s center (ideally the exact desired location).

• Depending on the results of the on-orbit validation, the team may attempt to perform orbital-raising maneuvers.

• At End of Life (EOL), the thrusters will be used to safely deorbit the CubeSat.
Secondary Goals – TEC

- Partner: TEC University (Costa Rica)
- Mission scope:
  - Measurement of water levels, temperature, acidity of wetlands in Costa Rica
  - Earth Observation and monitoring
### CubeSat Development

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility Study</td>
<td>Completed Late 2016</td>
</tr>
<tr>
<td>Phase 0/A</td>
<td>Completed Early 2017</td>
</tr>
<tr>
<td>Phase B (PDR)</td>
<td>Completed Oct. 2017</td>
</tr>
<tr>
<td>Phase C (CDR)</td>
<td>Expected Sep. 2018</td>
</tr>
<tr>
<td>Phase D (SC Ready)</td>
<td>Expected Dec. 2019</td>
</tr>
<tr>
<td>Phase D (Launch)</td>
<td>Expected Q1 2020</td>
</tr>
<tr>
<td>Phase E (Mission Op)</td>
<td>Expected Q1-Q4 2020</td>
</tr>
<tr>
<td>Phase F (Deorbit)</td>
<td>Expected Q1 2021</td>
</tr>
</tbody>
</table>

Version 3 = Hybrid of Version 1 and 2
Challenges

• Funding has been pouring in slowly
  • Makes planning difficult
• Turn-over rate
  • Lost approx. 60% of team in May 2018
  • Leadership within 2 years of graduating
• Propulsion system complexity
  • Long manufacturing times → not enough testing so far
• Slightly over-ambitious project
  • First CubeSat – relatively complex
• Red tape
  • Purchasing department is very slow
Industry Partners

Raytheon

dhv technology

PHILTEC®
FIBEROPTIC SENSORS

Special Thanks to:

NASA
Goddard
SPACE FLIGHT CENTER

NASA
Marshall Space Flight Center

AIAA
Shaping the Future of Aerospace