Monopropellant Micro Propulsion system for CubeSats

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Introduction

- High Performance CubeSat Propulsion will open up many opportunities
  - Decoupling of secondary payload (CubeSat) with primary payload orbit
  - Quick deployment of global constellations
- Goal is to develop 1U propulsion system to be integrated in 3U satellite
Why Monopropellant?

• Significantly higher performance (delta V) compared to cold gas

• Larger Thrust vs. Electric Propulsion
  – Needed for Orbit transfer

• Mature technology
  – Hydrazine is a known and mature hazard
  – New “Green” propellants still require analysis for range safety

• Less complicated than Bipropellant
  – Two separate tank and plumbing systems for fuel and oxidizer

• More volume efficient than Bipropellant
Requirements

• Meet CubeSat Standard
  – <1kg/unit
  – Aluminum 6061-T6, 7075 recommended
  – 75% of length must have rails with hard anodized surface
  – Not endanger primary payload

• Low Cost
  – ~$250k complete unit

• Address Range Safety constraints up-front
  – Small Propellant Quantity
  – Low operational pressure enables P-POD containment
  – Off site fueling/ Defueling as single integrated P-POD

• High Performance
  – Large delta V (~ 400m/s)
  – Thrust to weight ratio of 0.25
Design Philosophy

• Start with COTS components
  – Test and modify if necessary/possible
• Simplify
• Start with Thruster valve and design around it
• Develop cubic tank and cylindrical tank structure
  paper design in parallel
  – Compare theoretical performance of each
  – Continue design with best theoretical performance

Safety to personnel is highest priority
Micro Propulsion Details

- Miniature solenoid valve used for thruster valve
- 2 port design with a #10-32 threaded interface
- Mass = 37g
Micro-Propulsion Unit

- Attachment Point for additional Units
- Propellant Tank
- P-POD Guide Rails
- Drain and Fill Valves (Schrader)
- Thruster Micro-Solenoid Valves
- Thruster Combustion Chamber and Nozzle
Propulsion System Details

- CNC machined tank and cap
- P-POD rails integrated into tank structure
- Mounting Flange protrudes 6.5mm from tank edge
Propulsion System Details

- Tank and cap interface sealed with EDPM O-ring
- Stainless stud with laser drilled hole provides fluid path to thruster valve
- Stud uses EDPM o-ring to seal

Underside of cap with o-ring installed
Stainless stud with EDPM o-ring
Underside of cap with stud installed
Propulsion System Details

• Thruster valve mounts to stud and seats against cap boss (middle)
• Schrader valve mounted to cap used for fill/drain (right)
Propulsion System details

• Thruster made from stainless steel
  – Prototype (heavy) thruster shown (left)

• Catalyst made from platinum mesh and platinum/iridium wire “screens”
  – Screens are stacked and held by stainless fasteners
  – Number of screens can be varied during testing
Propulsion System Details

- Dry mass fraction for propulsion system unit = 0.45
- Expected delta V up to 400m/s
Test Plan

• Tank Burst Test
  – Investigate Failure Mechanism

• P-POD Integration
  – Verify smooth operation

• Hot Fire Test
  – Catalyst Function and integrity
  – Pressure range for proper thruster operation
  – Thrust measurements
  – Isp measurements

Micro Propulsion Module and P-POD test fit

Valve Cycling test under pressurization
Test Results

• Initial fit test successful
• Tank burst test revealed o-ring failure (Leak-Before-Burst)
  – Three tests performed using Nitrogen
  – Bolts yielded allowing main o-ring to be forced out of the groove at 2310 kPa, 2206 kPa, 2027 kPa
  – Consistent failure all three tests
  – Factor of Safety for leakage = 1.9, 1.8, 1.7

Micropropulsion system with o-ring failure
Test Results

• Stellar developed catalyst requires heating for proper decomposition
• Hot fire test revealed incomplete decomposition
• New catalyst design ready for testing
Future Work

• Propellant Management Device
  – Work in Progress
  – Testing needed
• Thruster Standoff Bracket
• Control and Navigation System
• Qualification Testing
Any Questions?

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