Hydrazine Propulsion Module for CubeSats

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Hydrazine Propulsion for CubeSats

• Low cost, propulsion-enabled CubeSats offer potential revolution in terms of mission capability per unit cost

• These include large scale orbit transfer for constellation deployment, de-orbit, orbit maintenance, attitude control, and momentum management

• Cost of access to space limits CubeSats to orbits which can be reached as secondary payloads

• A much expanded range of missions are possible but require greater $\Delta V$ than is practical using cold gas

• Aerojet is developing a 1U blow-down CubeSat Hydrazine Adaptable Monopropellant Propulsion System (CHAMPS) which will deliver a more than five-fold increase in total impulse compared to similarly-packaged cold gas systems

• The final flight system design will be fully compliant with Air Force Space Command Manual 91-710

• 1U CHAMPS readily mounts to 2U payloads to create mission-specific, mobile, 3U CubeSats
CHAMPS Development Schedule

Requirements Definition: April 2011
System Design: May-August 2011
Fabrication: Sept-Nov 2011
Testing: Jan-Feb 2012

PDR/CDR
Performance Assessment

SRR and Range Safety Compliance Assessment

Schedule updated from paper to reflect added design optimization effort
Thrust can be adjusted by over an order of magnitude by:

- Variation of operating pressure
- Substitution of interchangeable fluid resistors
CHAMPS Configuration and Features

• System Mounts inside standard 1U frame, allows solar panel cladding
• Aluminum construction, for optimal subsystem integration
• All thrusters point through single face to provide pitch/yaw/roll control
• Thrust vector orientation determined by nozzle design
• Inward thruster tilt minimizes plume impingement keep-out zone
• Service valve and isolation devices accessed through thrust plane
• Single electrical harness and connector to payload space

Adaptable Payload Mounting Interface
Piston Propellant Tank
MR-140A Thruster (4 places)
Paraffin-actuated Isolation Device(s)
(Service Valves)
(Details pending completion of range safety requirements assessment)
Aerojet MR-140A Thruster

• MKV-derived nano-optimized thrusters employed by CHAMPS are more than an order of magnitude smaller than those in conventional use

• 2 msec pulses enable fast response time, high control authority, and small MIB

Just like cold gas thrusters, a single monopropellant thruster can operate over a wide thrust range simply by controlling the feed pressure and/or propellant flow rate
1U hydrazine system delivers:

- 3× the performance of high-pressure (10 ksi) cold gas system
- 5× the performance of moderately high-pressure (5 ksi) cold gas system
- 10× the performance of low-pressure (3 ksi) cold gas system
- Safer and more reliable system with MEOP of only 500 psia

<table>
<thead>
<tr>
<th>Minimum Thrust Configuration</th>
<th>Maximum Thrust Configuration</th>
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<tbody>
<tr>
<td>BOL</td>
<td>EOL</td>
</tr>
<tr>
<td>Thrust (N)</td>
<td>0.24</td>
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<tr>
<td>Torque (N-cm) x</td>
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<tr>
<td>y</td>
<td>2.4</td>
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<tr>
<td>z</td>
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<tr>
<td>Minimum Angular Impulse Bit (N-cm-msec) x</td>
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<tr>
<td>y</td>
<td>6.0</td>
</tr>
<tr>
<td>z</td>
<td>0.52</td>
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<tr>
<td>Total Impulse (N-s)</td>
<td>760</td>
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</tbody>
</table>
Power and Thermal Management

• 6-8V, 4W max for 2 msec required to open each thruster valve

• Step-down to <1W to hold all valves open simultaneously

• \( \text{N}_2\text{H}_4 \) propellant must be maintained between 5 and 50°C
  – CHAMPS nests within primary structure to utilize waste heat from vehicle electronics as passive means to prevent propellant freezing
  – Tank, manifolds, and valves are conductively grouped to comprise a single thermal zone
  – Heat flow through system can be managed by adjustment of insulation applied to external (thrust) face of module
  – Patch heater can be added for missions with longer cold dwell periods

• Due to low total pulse and throughput requirements, baseline design does not carry catalyst bed heaters
  – Thrusters must be maintained above -40° to fire
  – Catalyst bed heaters can be added for missions requiring large number of starts
Controller

- Rad-tolerant FPGA-based control electronics flex circuit card following the Innoflight CubeSat approach can be packaged within the 1U CHAMPS:
  - Control pressure isolation device(s)
    - Activation of paraffin actuators
    - Multiple levels of safety inhibits to preclude unintended actuation
  - Control MR-140A thruster valves
    - Valve actuation
    - Provide valve voltage and current telemetry to C&DH computer
    - Current limiting to protect against valve coil short
  - Monitor CHAMPS pressure/temperature sensors and provide data to C&DH computer
  - Drive additional heater circuits as required
  - Can act as a node on a Space Plug-and-Play Architecture (SPA)-enabled CubeSat

- Commercial off-the-shelf (COTS) piece-parts

- Innoflight's “Onion-layered” protection features guard against Single-Event Effects (SEE), including memory Error Detection and Correction (EDAC) and multiple levels of watchdog timers

- Extra processing, memory, and Input/Output (IO) resources available:
  - Can perform full CubeSat 3-axis Attitude Control System (ACS) if interfaced with AODC sensors and external (non-propulsive) actuators
Conclusions

• Hydrazine can provide much expanded range of missions for CubeSats

• 3 to 10× more $\Delta V$ than cold gas

• Aerojet CHAMPS will be available to provide up to 800 N-sec impulse by mid 2012

• Fully compliant with range safety requirements of Air Force Space Command Manual 91-710