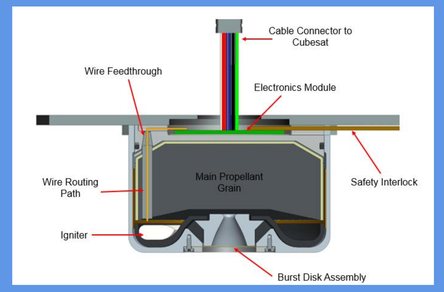
Design and Qualification of DSSP's CubeSat Delta-V Motor (CDM-1)

Jason Thrasher and Mike McPherson
Digital Solid State Propulsion, Inc.

Firing of a CDM-1 development motor in the DSSP test cell

I. Design

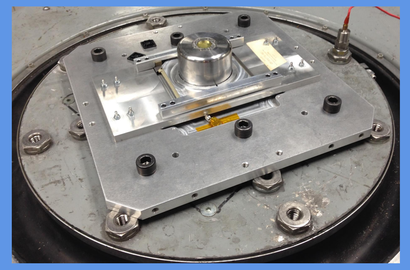
Digital Solid State Propulsion (DSSP) was given the challenge of developing a propulsion unit that can deliver >47.5 m/s of delta-V to a 3U CubeSat, but limited to 5W from a 5V bus and to the "tuna can" of the 3U+ configuration without intruding into the interior volume of the spacecraft.
The design that followed was an AP/HTPB fueled solid rocket motor in an end-burning configuration that is lit by a NaClO3 igniter that requires 5W from a 5V bus to ignite. The unit mounts to the aft end of a 3U CubeSat structure using 4x Pumpkin Solar Panel clips (PN: 711-00346)



Section view of the CDM-1 motor

II. Qualification

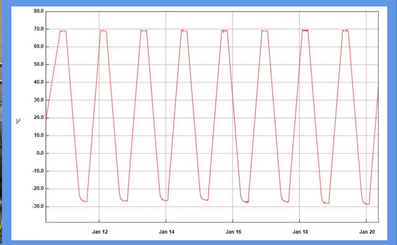
Once the design and development testing was completed, four flight-like motors were constructed and qualified through rigorous testing. The first test the motors were subjected to was simulated launch vibration. This test was performed by Martin Testing Labs of McClellan, CA to the requirements of the NASA-GEVS-SE document.



A CDM-1 unit on MTL's vibration test stand

The health of the motors were determined via non-destructive testing post-test and then they continued to simulated on-orbit survival in a thermal vacuum chamber that was developed in-house at DSSP. The test consisted of seven cycles of a 10°C/hr ramp to a max of 70°C, a 4 hr soak at 70°C, a 10°C/hr ramp down to -28.5°C and a 4 hr soak at that minimum. This thermal cycling occurred at a pressure of ~50 mTorr.

DSSP Thermal Vacuum Chamber

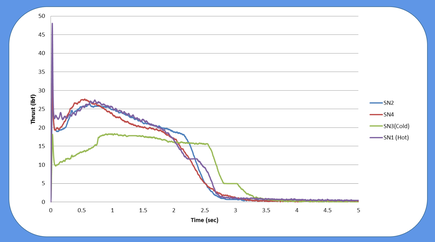


Graph of qualification thermal cycling temperatures

Again health of the motors were determined post-test and the four test units completed qualification testing by being fired in a vacuum chamber. This final test was also performed at DSSP in a large chamber developed for this purpose. Two of the motors were tested at ambient pressure with one of the other units being tested at a high temperature and the other tested at a low temperature.

DSSP CDM-1 test vacuum chamber

One of the CDM-1 units firing in the vacuum chamber



Thrust Data from CDM-1 qualification testing

III. Safety

Because CubeSats are usually launched as secondary payloads, safety features of the motor are emphasized in order to quell the fears of the primary payloads and launch providers. These features include:

- A Safety Interlock that is a physical switch for transporting the motors and is removed before flight.
- An Arm command that is required of the Fire Control electronics before a fire command can be received.
- A minimum time of the fire command (5V, 5W for 5 sec) before the ignitor will go off.
- Press pins that hold the motor case together that cannot be removed prevents tapering with the motor after assembly
- A sealed burst disk that protects the interior of the unit from environmental factors such as humidity and Electro-Static Discharge.

These features culminated in a Department of Transportation shipping classification of 1.4C following testing at SMS of West Jordan, Utah

Result images from DoT Hazard Classification Testing at Safety Management Services

IV. Performance

MOTOR DIMENSIONS
Motor diameter (cm)……..6.40
Motor length (cm)……..4.70
Total loaded mass (g)…..……..459.5

MOTOR PERFORMANCE (STP)
Burn time/action time (sec)……2.98
Ignition Delay time (sec)……10.8
Total impulse (N-s)……226.4
Effective vacuum specific impulse (sec)……235
Burn time average thrust (N)……76.5
Maximum thrust (N)……186.8

Orbital lifetimes for CubeSats have mostly been set by the orbit into which they were delivered as a secondary payload. One example is the 250km orbit of the Antares A-One launch, which gave an orbital lifetime to the CubeSat deployed of about two weeks. This motor's performance would have extended the lifetime of the example Antares A-One deployed CubeSats to about 2-3 months.

To protect the space environment, another desire of the industry is a more rapid deorbit than able without the assistance of a deorbit module. The international standard is to reenter the Earth's atmosphere in less than 25 years after the end of mission of the spacecraft. Abiding by this standard would limit a CubeSat to a maximum circular orbit of about 575 km, but the CDM-1 would allow up to 700 km circular orbits if it is used to decrease the perigee at the end of the mission.

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