HuskySat-1 Pulsed Plasma Thruster Effects on the Satellite Orbit

HuskySat-1 has an on-board pulsed plasma thruster (PPT) mounted to provide thrust along the Z axis. The PPT is comprised of two concentric electrodes with a solid sulfur fuel-puck placed between the electrodes. A 20uF bank of capacitors charged to 1kV provides the 10J energy across the electrodes for the pulse, which is initiated by a high-voltage low-current ignitor. This allows the breakdown of the stored energy across the surface of the sulfur, which ablates and ionizes 10's of micrograms of sulfur fuel per pulse. The system requires a ground command to pulse. As such, it can only be pulsed once every 4 seconds while in contact with the Huskysat ground station. The satellite has contact with the ground station ~5 out of every 14 orbits for ~ 3 minutes each pass.

Assumptions:

1. The thruster has a window of about 10 weeks of operation, over which a maximum of 1000 pulses total may be tested. In one day, no more than 20 pulses will be fired, with a maximum of 100 pulses per week. The initial planned testing is less than 20 pulses per week.

2. To maximize possible calculated effect on the orbit, it is assumed that all thrust will be in the RAM direction. This will not be the case on-orbit.

Summary of Calculated Values:

1. The maximum total delta-V from the thruster over 10 weeks is 0.15 m/s.

2. The maximum total delta-V from one day of operation is .0031 m/s.
   a. This could occur in a single orbit, for with the drag contribution is ~0.00033 m/s
   b. The drag contribution in a single day is ~0.0051 m/s

3. The upper end of planned operations delta-V over 10 weeks is 0.091 m/s.

4. The delta-V from drag over the 10 weeks is approximately -0.36 m/s.

5. A very conservative estimate of drag was used considering low solar activity to give an estimate on the drag force of 1.88E-7 Newtons over this time, the total delta-V over 10 weeks including the drag force is given below for each situation, and at no time do we overcome the average drag force for that 10 week period.

Because the satellite has an estimated lifetime of about 3.5 years (about 180 weeks) discounting propulsion effects, and because the total effect of the propulsion over 10 weeks is less than half the effect of drag for those same 10 weeks, the effect of propulsion on the demise date, is believed to be within the uncertainty range of the lifetime estimate.

The expected case, as compared to the worst case, is that the delta-V from the propulsion will be in random directions, and to a great extent cancel itself out.

Notes on calculation:
Circular Orbit at 500 km:
v = 7.6126798 km/s
Force drag = 0.188 μN (low estimate)
Period: 5.6768E3 seconds -> 96.133 min ~>1.6 hours
24 hr / 1.6hr ~= 15 orbits/day
15 orbits/day * 7 days/week = 105 Orbits/Week
105*(5/14) = 37 Seattle Passes per week
100/37=2.7 maximum average pulses per pass, used for calculation below

Estimate: 2.7 pulses on every 3rd orbit

v_Final (No Drag) = 7.61283 km/s	dv = .15 m/s increase	
v_Final (w/Drag) = 7.61247 km/s	dv = .21 m/s decrease	**961 Pulses**

Firing One Initial Burst of 20 Pulses

v_Final (No Drag) = 7.6126829 km/s	dv = .0031 m/s increase	
v_Final (W/Drag) = 7.6123274 km/s	dv = .35 m/s decrease	**20 Pulses**

Firing 20 Pulses per week (modeled as a 20 pulse pass once every 37 orbits)

v_Final (No Drag) = 7.6127709 km/s	dv = .091 m/s increase	
v_Final (w/Drag) = 7.61241489 km/s	dv = .26 m/s decrease	**580 Pulses**

Not Firing

v_Final (w/ Drag) = 7.61232427 km/s	dv = .36 m/s decrease	**0 pulses**