16.522 Space Propulsion
Homework #3

Handed: 2/19/04
Due: 2/26/04

One of the difficulties in using low thrust engines to transfer sensitive payloads form LEO to GEO is the degradation of the solar array and other electronics during the long stay in the Van Allen belts. Since this effect is almost non-existent above some 20,000 Km (radius), an intermediate strategy being seriously considered is to go with some form of chemical propulsion to an orbit at R=20,000 Km, then use the satellite's solar arrays to power its final ascent to GEO with an electric thruster.

We would like to conduct a preliminary assessment of this strategy for a hypothetical geosynchronous communications satellite. Here are the ground rules:

-Start in a 300 Km circular orbit (inclination i=28.5°) with a mass of 10,000 Kg
-The satellite has in all cases an installed array power of 6 KW
-For the chemical burns, assume solid propellant motors, with Isp=300 sec and discard the casing (10% of propellant mass) after each burn.
-For the plane change to equatorial orbit, consider two limiting possible scenarios:

(a) Plane change at second chemical burn only
(b) Plane change by low-thrust engine only

-Operate electric thrusters at constant (full) power, therefore constant thrusts and flow rate
-Consider three types of electric thrusters:

(a) Arcjet (Isp=600s, $\eta = 0.40$)
(b) Hall thruster (Isp=1600s, $\eta = 0.55$)
(c) Ion engine (Isp=2500s, $\eta = 0.75$)

The cost in LEO orbit is assumed to be the same in all cases. The revenue expected over 10 years is $100,000 per Kg of payload in GEO. The cost incurred for the delay due to deployment with low thrust is $2M/month. When calculating the GEO payload with electric thrusters, discount 20 Kg/KW for the extra mass of the thrusters and their Power Processing Units (but not the array, which is part of the payload).

Compare the various options on the basis of expected revenue, minus deployment cost.