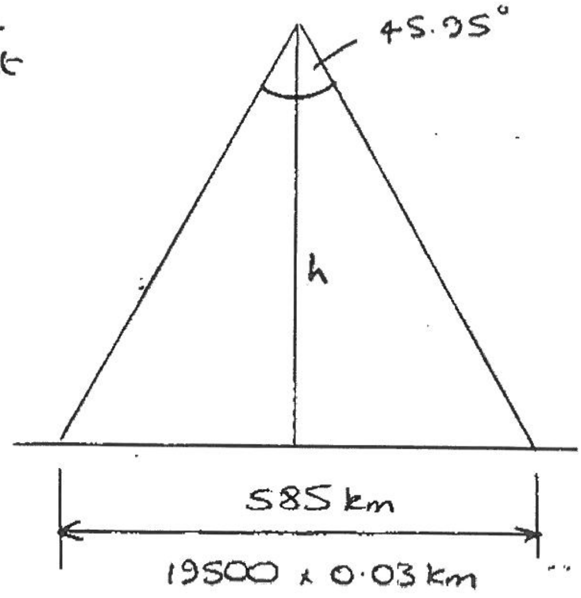
1. DISASTER MONITORING SATELLITE

(i) swath - width of instrument



(ii) Approx orbital height (for ~30m resolution)

$$= \frac{585/2}{\tan\left(\frac{45.95}{2}\right)} = \underline{689.92 \text{ km.}}$$

(iii) For complete global coverage, distance between ground tracks at the equator is required to be $\approx 0.9 \times$ swath-width $= 527$ km $= d$

From $d = \frac{2\pi R_E}{n} \Rightarrow n = \frac{2\pi R_E}{d} \doteq 76.$

(iv) @ 690 km altitude, orbit period

$$\tau = 2\pi\sqrt{\frac{a^3}{\mu}} \doteq 5900 \text{ s} \quad (5913.66 \text{ s})$$

which gives $\approx \frac{86400}{5900} = 14.6$ orbits per day

$\therefore$ we want $\frac{m}{n}(86400) = \tau \doteq 5900$

$$\therefore m = \frac{5913.66\,(76)}{86400} \doteq \underline{5}$$

(v) $a = \left\{ \mu \left(\frac{\tau}{2\pi} \right)^2 \right\}^{1/3}$.

so $n \simeq 76$, $m \simeq 5$.

(n, m)	τ (sec)	a (km)	$h = a - R_E$ (km)
(76, 4)	4547.37	5932.43 !	
(76, 5)	5684.21	6883.98	505.98
(76, 6)	6821.05	7773.68	1395.68

So choose $(n, m) = (76, 5)$ (a bit low – will impact orbit control).

height = 506 km.

(vi) Inclination $\cos i = \dot{\Omega}\, a^{3.5} / (-2.0647 \times 10^{14})$

where $\dot{\Omega} = \frac{360^\circ}{365.25 \text{ days}} \simeq 0.986^\circ/\text{day}$.

$\underline{i = 97.43^\circ}$.

(note actual resolution : $= \frac{506 \tan\left(\frac{45.95}{2}\right)}{19500/2}$

$= \underline{22\,\text{m}}$.)

(vii) Change in orbit height per orbit

$$\delta a = -2\pi \rho \frac{SC_D}{m} a^2$$

use $\rho = 2.5 \times 10^{-13}$ kg/m^3.

$S = 1\ m^2$

$C_D = 2.2$

$m = 150$ kg.

$a = 6378 + 506$ km

$= 6884$ km

$\Rightarrow \delta a = 1.092$ m / orbit

(viii) $$\delta \tau = \frac{3\pi}{V} \delta a$$ where $V = \sqrt{\frac{\mu}{a}} = 7.6094$ km/s

$\Rightarrow \delta \tau = 0.00135$ sec/orbit

(ix) $\epsilon_0 = \pm 0.5$ km.

$$\delta \lambda = \frac{2\epsilon_0}{R_E}\left(\frac{180^\circ}{\pi}\right) = 0.00898^\circ$$

$$\Delta t_0 = \frac{\delta \lambda}{\omega_E}$$ where $\omega_E = 0.004178^\circ$/sec.

$\Rightarrow \Delta t_0 = 2.15$ sec.

$$k = \sqrt{\frac{2\Delta t_0}{\Delta \tau}} = 56.439 \simeq \underline{\underline{56}}$$

$$\Delta a_{decay} = 2k\,|\delta a| = \underline{123.263\ m}$$

122.304 after 56 orbits

$$\Delta T = 2k\tau_0 = \underline{7.43\ \text{days}}$$

7.368 days

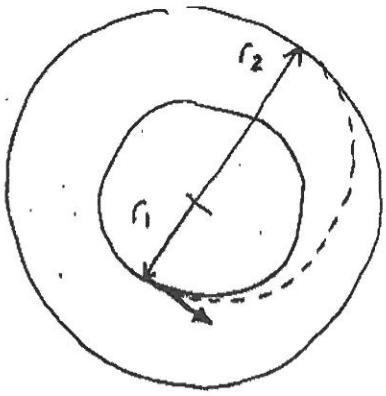
(x)

Boost orbit $h_{low} = 6884 \times 10^3 - \frac{1}{2}(123.3)\,m$

to $h_{high} = 6884 \times 10^3 + \frac{1}{2}(123.3)\,m$

every 7.43 days.

(xi) <u>Burn 1:</u>
Hohmann Transfer



<u>Energy equation: on transfer</u>

$$\frac{V_{TP}^2}{2} - \frac{\mu}{r_1} = \frac{-\mu}{2a_T}$$

$$\text{where } a_T = \frac{r_1 + r_2}{2}$$

$$\Rightarrow V_{TP}^2 = 2\mu\left[\frac{1}{r_1} - \frac{1}{r_1 + r_2}\right]$$

$$r_1 = 6883.98 - \frac{0.1233}{2} = 6883.91835\ km$$

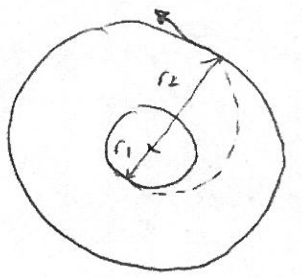
$$r_2 = 6883.98 + \frac{0.1233}{2} = 6884.04165\ km.$$

$$\therefore\ V_{TP} = 7.609440694\ km/s$$

on circular orbit $V_{c1} = \sqrt{\frac{\mu}{r_1}} = 7.60940662\ km/s$

$$\therefore\ \Delta V_1 = V_{TP} - V_{c1} = 0.0000340736\ km/s$$
$$= \underline{3.40736\ cm/s}$$

(xi) Continued. Burn 2



Energy equation on transfer

$$\frac{V_{TA}^2}{2} - \frac{\mu}{r_2} = \frac{-\mu}{2a_T}$$

where $a_T = \dfrac{r_1 + r_2}{2}$

$$\Rightarrow V_{TA}^2 = 2\mu\left[\frac{1}{r_2} - \frac{1}{r_1 + r_2}\right]$$

$$\Rightarrow V_{TA} = 7.609304401 \text{ km/s}$$

on circular orbit $V_{c2} = \sqrt{\dfrac{\mu}{r_2}} = 7.609338474$ km/s

$$\therefore \Delta V_2 = V_{c2} - V_{TA} = 0.000034073 \text{ km/s}$$
$$= \underline{3.4073 \text{ cm/s}}$$

$$\therefore \underline{\Delta V_{TOT} = \Delta V_1 + \Delta V_2 = 6.8147 \text{ cm/s}}$$

for one cycle.

(xii) N^o of orbit cycles $= \dfrac{\text{s/c life}}{\text{cycle time}} = \dfrac{3 \text{ years}}{7.43 \text{ days}}$

$$= 147.476$$

$$\therefore \text{TOTAL } \Delta V = 147.5\,(0.068147) \text{ m/s}$$
$$= 10.05 \text{ m/s.}$$

(xiii) Assume $0.05°$ inclination correction per year.

$$\Delta V = \delta i\, V$$

so for 3 year life $\Delta V_{inc} = 3(0.05°)\left(\dfrac{\pi}{180°}\right)(7609.4)$ m/s

$$\approx 19.92 \text{ m/s.}$$

$\therefore$ WORST CASE ΔV required $\doteqdot$ 30 m/s

(xiv) Fuel mass:

$$M_e = M_0 \left(1 - \exp\left[-\frac{\Delta V}{V_{ex}} \right] \right)$$

$V_{ex} = 1766\ m/s$ (same as SPOT)

$M_0 = 150\ kg$

$\Rightarrow \underline{M_e = 2.5\ kg}$ $\quad\quad \Delta V = 30\ m/s.$

$\underline{+\ \text{margin.}}$

(xi) sampling time

$$t_s = \frac{d_{pixel}}{V_{gd.}}$$

$$V_{orb} = \sqrt{\frac{\mu}{a}} = 7.6094 \text{ km/s}$$

$$V_{gd} = V_{orb}\left(\frac{R_E}{a}\right) = 7.0501 \text{ km/s}$$

$$t_s = \frac{22}{7050} = \underline{0.0031 \text{ sec.}}$$

Every t_s sec, 19500 CCD elements are read & digitised as 8-bit word.

$$R_b = \frac{19500\ (8)}{0.0031} = 49.99 \times 10^6 \text{ bps}$$