PREFERRED RELIABILITY PRACTICES

EARTH ORBIT ENVIRONMENTAL HEATING

Guideline:

Use the currently accepted values for the solar constant, albedo and earth radiation when calculating the heat balance of earth orbiters. This practice provides the heating rates for the black body case without consideration of spectral effects or collimation.

Benefit:

Consideration of the solar, albedo, and earth radiation thermal inputs, including seasonal variation with tolerances, is required to accurately predict the thermal environment of orbiting devices.

Center to Contact for More Information:

Goddard Space Flight Center (GSFC)

Implementation Method:

SOLAR CONSTANT

The nominal solar constant value is 1367.5 W/m^2. The variation of the earth-sun distance causes a ± 3.5% seasonal variation from nominal. The accuracy of the solar constant is taken as ± 0.5%. The following are the values for various seasons in the northern hemisphere.

NOMINAL	1367.5 W/m^2
WINTER	1422.0 W/m^2 (NOM + 4.0%)
SUMMER	1318.0 W/m^2 (NOM - 4.0%)

*ALBEDO FACTOR**

The nominal albedo factor is 0.30. The variation around the nominal should be ± 0.05. No variation during the sunlit portion of a given orbit should be assumed unless extremely light weight items

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*Note: Since earth temperature and albedo vary with latitude, as the orbit approaches either extreme of a polar or equatorial orbit, further study of the literature should be made. (see AIAA - 87-1596)

EARTH ORBIT ENVIRONMENTAL HEATING

are being considered. Programs that compute albedo energy should use 0.35 (hot case), 0.30 (nominal case), and 0.25 (cold case), respectively.

*EARTH EMITTED ENERGY**

The nominal earth temperature for earth emitted IR energy is 255° K. This temperature produces a heating rate of 241 W/m^2. A reasonable variation can be obtained by maintaining consistency using the following relationship between Solar, Albedo, and Earth Emitted Energy:

Earth Emitted Energy = [(1-Albedo Factor) x Solar Constant] / 4.0

Table 1 shows the variations in Earth Emitted Energy that result from using the above recommended Solar and Albedo ranges.

Software programs that compute Earth Emitted Energy should use the appropriate hot, nominal, or cold case Solar and Albedo values; and the corresponding black body Earth temperature to achieve an energy balance.

REFERENCES FOR QUICK CHECKS OR SIMPLE CALCULATIONS

Hand calculations should be made to verify that computer outputs of heating values for flat surfaces of known orientation and minimal reflected inputs from other surfaces are reasonable. Hand calculations also may be necessary when time does not permit a computer study. A check of incident Albedo energy to a flat plate at various altitudes and orientations can be made by using TN-D 1842 "Earth Reflected Solar Radiation Incident Upon an Arbitrary Oriented Spinning Flat Plate," by F. Cunningham. Figures 1 through 9 show the orbit-averaged incident Earth and Albedo energies to an Earth-oriented flat plate at various altitudes and orbit/sun angles. Eclipse factors for elliptical orbits are provided in "Calculation of the Eclipse Factor for Elliptical Satellite Orbits", by F. Cunningham. A hand calculation of incident Earth Emitted Energy to a flat plate at various attitudes and altitudes also is possible. Figure 10 shows the instantaneous geometric shape factor for a planar surface as a function of altitude and attitude (h/R is the ratio of the orbit altitude to the Earth radius). The earth radius is 6,365 km. The incident Earth Emitted Energy is found by multiplying the shape factor times the black body emissive power at the earth temperature. For an altitude of 1,000 km and a flat plate whose normal is 90 degrees to the nadir (λ = 90); h/R = 0.157, which gives a shape factor of 0.19. The Earth Emitted Energy incident on the plate is 0.19 x 241 W/m^2 or 46 W/m^2.

TABLE 1. VARIATIONS IN EARTH EMITTED ENERGY FOR

EARTH ORBIT ENVIRONMENTAL HEATING

RECOMMENDED SOLAR AND ALBEDO RANGES*

SOLAR CONSTANT (W/m^2)	ALBEDO FACTOR	EARTH EMITTED ENERGY (W/m^2)	EQUIV. EARTH TEMP (ºK)
NOMINAL 1368	0.25 0.30 0.35	256 239 222	258 254 250
WINTER SOLSTICE 1422	0.25 0.30 0.35	267 249 231	262 258 253
SUMMER SOLSTICE 1318	0.25 0.30 0.35	247 231 214	256 251 246

* For use in Orbit Average Analyses

NOTE: Since earth temperature and albedo vary with latitude, as the orbit approaches either extreme of a polar or equatorial orbit, further study of the literature should be made (see AIAA - 87-1596).

EARTH ORBIT ENVIRONMENTAL HEATING

EQUIVALENT SINK TECHNIQUE

The equivalent sink technique can be used by replacing all surrounding surface radiant interchanges and the absorbed Solar and Earth energies to node i with a single radiation coupling to a single node at temperature T sink.

To derive the equation for this sink temperature, first consider an energy balance at node i where all the inputs are treated as gross inputs and node i has a view to space of 1.0

(1) $$+ \; Q_{IR} \quad + \quad Q_I \quad + \quad \sum_{n=1}^{k} \mathscr{F}A_{i-n}\sigma T_n^4 \quad = \; \epsilon_i$$

From planetary flux program (TRASYS or SSPTA) Model program

From thermal program (SINDA) results obtained from Geometric Math (GMM) radiation exchange

Where:

Q_{s+A} = absorbed solar and albedo energy
Q_{IR} = absorbed earth IR energy
Q_I = internal power dissipation
σ = Stefan−Boltzmann constant
$\mathscr{F}A_{i-n}$ = Radiant interchange factor
A_i = Area of node i
ϵ_i = emissivity of node i

Next consider the equivalent sink energy balance situation: $Q_I \rightarrow i \xrightarrow{\epsilon_i A_i} T_s$

(2) $$Q_I \;=\; \epsilon_i A_i(\sigma T_i^4 - \sigma T_s^4) \;=\; \epsilon_i A_i \sigma T_i^4 \;-\; \epsilon_i A_i \sigma T_s^4$$

Solving (1) for Q_I and setting equal to the right side of (2) gives:

(3)
$$\epsilon_i A_i \sigma T_s^4 \;=\; Q_{s+A} \;+\; Q_{IR} \;+\; \sum_{n=1}^{k} \mathscr{F}A_{i-n}\sigma T_n^4$$
$$\sigma T_s^4 \;=\; \frac{Q_{s+A} \;+\; Q_{IR} \;+\; \sum_{n=1}^{k} \mathscr{F}A_{i-n} \; \sigma T_n^4}{\epsilon_i A_i}$$

The equivalent sink for node i may be determined from the detailed thermal math model by determining the adiabatic temperature of node i when node i is disconnected from internal heat

EARTH ORBIT ENVIRONMENTAL HEATING

paths and heat dissipations. For a transient situation, node i must be an arithmetic node or a low mass node.

Technical Rationale:

Thermal analysis of an earth orbiting spacecraft requires the accounting of incident thermal energy from all external sources. The most significant external sources of energy incident on the spacecraft are the sun, the thermal radiation of the earth, and the solar energy reflected from the earth (albedo). The modification of the energy incident on the spacecraft due to the earth-sun distance variation, and the accuracy of the measurements of the solar constant, are of sufficient magnitude to be important parameters in performing a thermal analysis.

Impact of Nonpractice:

Not considering the variations in the environmental thermal effects as described in this guideline will result in an incomplete thermal analysis. The temperature variation of the spacecraft could be grossly underestimated, thereby reducing its reliability.