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NASA TECH BRIEF

Ames Research Center

Analysis of Orbital Heat Transfer

The problem:

To provide rapid estimates of the approximate thermal conditions in a given orbit so that the magnitude of spacecraft thermal problems can be assessed without need for parametric studies with digital models.

The solution:

Graphical representation of orbital heat balance in the form of polar diagrams obtained from integral expressions of orbital heat transfer whereby quantities of heat are represented as areas swept by "thermal radii."

How it's done:

Analogous to the mechanical description of orbits (Kepler's laws) by a position vector as a function of true anomaly, the radiation incident, absorbed, or emitted by a surface element in orbit may be described as a function of true anomaly by a "thermal radius," $\phi = rf^{1/2}$, where r is a dimensionless position radius ($r = 1$ at zero altitude) and f is the radiation view factor. The properties of ϕ include:

a) In the case of constant irradiance or emission, the thermal orbit described by the thermal radius is geometrically similar to the mechanical orbit, and the areas swept by the thermal radius are proportional to time.

b) For incident or absorbed radiation obeying the inverse-square law, the thermal radius is constant, and the thermal orbit associated in a central force field with any closed mechanical orbit is a circle (whereas, in the case of a hyperbolic or parabolic orbit, it is an arc of a circle).

c) In an inverse-square radiation field, the upper limit of the thermal radius is 1; accordingly, the upper limit of the average incident planetary (or solar) radiation per orbit is the product of the appropriate source constant and the ratio of the cross-sectional area of the planet (or sun) to the area of the orbit (the latter represents the upper limit of the orbital-average view factor, which is a function of position and orientation in orbit).

The calculation of thermal radii for planetary and albedo radiation is facilitated by the use of graphical plots of dimensionless position radius *vs* thermal radius for flat plate exposed to planetary radiation and to albedo radiation; rapid construction of overall heat-balance diagrams is possible.

For any orbit in a central force field, and with incident radiation obeying the inverse-square law (e.g., solar system), equal angles swept by the position radius correspond to equal amounts of (cumulative) incident radiation.

Note:

Requests for further information may be directed to:

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