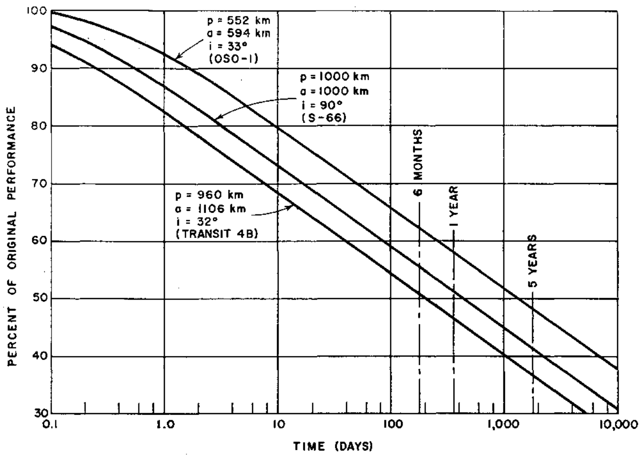

Fig. 7 Solar cell performance as a function of time for several orbits

preliminary. The time required to deteriorate to any particular percent of the original solar cell performance is probably accurate within a factor of 3. It should be stated further that these curves are for the short circuit current (at 0.2 v/cell) for *P*-on-*N*, "blue-sensitive" solar cells with a 6-mil cover glass. The use of thicker protection for the solar cells and especially the use of *N*-on-*P* solar cells or a combination of the two could have a significant effect in decreasing the rate of degradation.

Fig. 8 shows a preliminary concept of the artificial radiation belt as deduced by W. N. Hess from Ariel, Injun I,[7] Telstar, and TRAAC satellite data.[8] The radiation levels shown at altitudes greater than the 2 earth radii may be due in large part to natural Van Allen belt electrons rather than as a result of the nuclear test. However, whatever the cause of their presence, they appeared to be there in late July 1962.

Conclusions

As a result of the high altitude nuclear explosion over Johnston Island on July 9, 1962, an intense electron radiation belt has been trapped in the earth's magnetic field. This artificial radiation belt can cause silicon solar cells to deteriorate at a much greater rate than was previously expected as a result of protons in the natural Van Allen radiation belt. At the altitudes of instrumented satellites, the electron radiation belt does not appear to be diminishing at a rate fast enough to offer relief from this new environment in the near future. However, Anna satellite data from late in November 1962 have shown that the belt is down by a factor of approximately 3 since July 9 as far as the damaging effects of solar cells are concerned. Therefore, for late November 1962 the curves of Fig. 7 show approximately 3 times the expected rate of degradation. To provide a satellite solar cell power system with a long life capability, it will be necessary to provide a large margin of over-design in the initial power-generating capability of the solar power system. The use of *N*-on-*P* solar cells will have a significant effect in increasing the life of the power generating system of the satellite. The use of thick cover slides for the solar cells will result in a decrease in the rate of degradation. The extent of this protection cannot be determined accurately until the energy spectrum of the trapped particles is better defined.

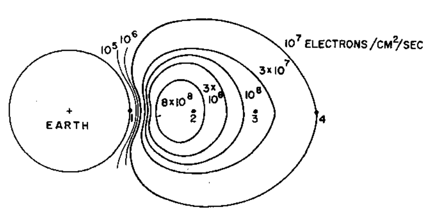

Fig. 8 Preliminary concept of the artificial electron radiation belt

Acknowledgment

The author wishes to acknowledge the invaluable assistance of James W. Teener, of the Applied Physics Laboratory, for performing the numerous computations necessary to obtain the solar cell performance data presented herein.

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Comments on "Re-Entry Trajectories: Flat Earth Approximation"

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In a recent paper by Blum,[1] an excellent study is found on re-entry trajectory calculations. There is, however, a technical error in the first two equations which is propagated throughout the remainder of the paper. Although the result of this error is slight and does not invalidate the calculations given by Blum, it is an error commonly made by others and will now be discussed.

In deriving Blum's Eq. (1), one might obtain

$$d^2y/dt^2 = -g - (\rho A C_D/2m)V(dy/dt) \tag{1}$$

where g is the gravitational acceleration that is, in general, a function of position, and where m is the mass in gravitational units. Now, in order to introduce the ballistic parameter β (a constant), which is defined by

$$\beta = C_D A/W \tag{2}$$

Received by ARS September 10, 1962.

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[1] Blum, R., "Re-entry trajectories: flat earth approximation," ARS J. **32**, 616–620 (1962).

one must change units of m from gravitational units to absolute units, using

$$W = mg_0 \quad (3)$$

Here, g_0 is a conversion factor and definitely a constant. (It is unfortunate that people associate g_0 with gravity.) One now has

$$d^2y/dt^2 = -g - (g_0\beta\rho/2)V(dy/dt) \quad (4)$$

In similar fashion, one gets

$$d^2x/dt^2 = -(g_0\beta\rho/2)V(dx/dt) \quad (5)$$

The remaining equations in Blum's paper are now easy to correct, as follows. Wherever g is multiplied by β, it should be the conversion factor g_0, and wherever g is divided by V^2, this is the gravitational acceleration $g(y)$. In addition to this, the statements under Blum's Eq. (26) should be modified, and his Eq. (45) should read

$$J(y) = g_0 \int_0^y \rho dy \quad (6)$$

which is easier to evaluate.

As mentioned earlier, these corrections do not invalidate the calculations made in the paper, nor is it this author's purpose to be supercritical of a fine paper. However, this failure to distinguish gravitational acceleration from the conversion factor relating mass in gravitational units to mass in absolute units is a common error and leads to much confusion. It is unfortunate that the word "pound" is allowed to serve the dual role of a force unit as well as a mass unit and that a hybrid system is used continually. It would be better if either the gravitational system of units were adopted consistently and the slug allowed to become a respectable mass unit for all technical work, or the absolute system of units were adopted with stature given to the poundal as a force unit.

Comment on "Use of Ballistic Pendulums With Pulsed Plasma Accelerators"

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IN a recent note,[1] the authors concluded on the basis of only probe and calorimetric measurements that the impulse delivered by a pulsed plasma accelerator could not be determined reliably by a ballistic pendulum. This result is not surprising, for, even based upon the most elementary mechanical considerations, the nature of the momentum transfer from a pulsed plasma accelerator to the pendulum at best can be estimated only within a factor of 2. Indeed, matters are generally worse in that pressure force terms, temporal momentum variations, and ablative contributions from the surface of the pendulum introduce further departures between indicated impulse and the actual impulse. An excellent discussion of thrust of intermittent propulsive devices is presented, for example, in Ref. 2.

The shortcomings in determining reliable, accurate impulse data of a pulsed plasma accelerator by means of a ballistic pendulum have been reported previously.[3,4] In Ref. 4, impulse measurements of a pulsed plasma accelerator as obtained directly on a thrust stand have been compared with the results obtained by using a carefully designed ballistic pendulum. The ballistic pendulum data indicated impulse levels five times larger than measured on a thrust stand that had the entire accelerator system mounted on it. The tendency to obtain a larger impulse with a ballistic pendulum than on a thrust stand apparently has been observed by other investigators also.

A recent conference[5] concerned with the exchange of information on thrust, mass, and power measurements of electric propulsion devices, and attended by those companies actively engaged in the field of electric propulsion, revealed that investigators in the electric propulsion field are using direct measuring thrust stands for performance analysis. None of the attendees reported the use of a ballistic pendulum.

Received by ARS October 25, 1962.

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Comment on "Stresses and Strains in Solid Propellants During Storage"

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AN analysis of the expected deformation in a perforated, horizontal grain of viscoelastic propellant attached to a rigid case has been reported recently by Lianis.[1] However, as noted by Lianis, the calculated displacements were suspiciously large, and long-time creep data were needed for a better evaluation of the expected deformation.

The results of long-time creep compliance tests conducted in this laboratory show, as Lianis suspected, that extrapolation of the relatively short-time compliance data reported by Blatz[2] is not valid but results in an inordinately large predicted displacement.

Creep data for two propellants with different binder systems are shown in Figs. 1 and 2. As the figures indicate, it is possible to fit the data at long times (>50 hr) with a constant creep rate function, but it is not possible to deduce this function from creep tests of only a few hours duration.

For purposes of comparison with Lianis' results, one calculates that for the propellant shown in Fig. 1, in a configuration wherein $R = 20$ cm and $\mu = 2$, the maximum surface radial displacement u is

$$u_{\max} = \{39.0 + [0.045(t)/\text{hr}]\} \times 10^{-3} \text{ cm}$$

Received by ARS October 8, 1962.

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