7.1. General

The Early Bird synchronous satellite, launched on April 6, 1965, was placed into service over the Atlantic Ocean at 25° west longitude on June 28, 1965. After approximately three and half years of service, it was retired on January 20, 1969 and put in reserve. On June 29, 1969, it was reactivated and retired again on August 21, 1969. Since then, the satellite is no longer useful for communications.

The satellite has a basically cylindrical shape of diameter 71.7 cm and height 59.0 cm. Its in-orbit final mass (no more propellant) is 34.9 kg. A 60 cm long antenna projects from one of the cylinder's bases and is oriented to coincide with the cylinder axis. The satellite has a corrective-ΔV capacity of 90 mps. It spins at a rate of 120-180 rpm with the antenna along the spin axis, which is oriented normal to the orbital plane. The satellite's effective area to mass ratio is 0.0148 m²/kgm (0.0722 ft²/lbm). This value will be useful in computing the effect of the solar radiation force on the satellite orbit.

The last maneuver performed on the Early Bird synchronous satellite occurred on May 27, 1970. After that maneuver, the satellite had no additional propellant on board and was therefore considered as a 'dead' one.

In order to verify the theory presented in the previous chapters, we shall compare our analytically predicted orbital elements with those derived from the tracking data and the numerically integrated results of the Early Bird. Both of them were provided by the Communications Satellite Corporation. After evaluating various constants in our orbital parameters in terms of the initial conditions of the Sun, Moon, and the Early Bird in relation to the Earth, the solutions to these parameters can be written out directly from the derived expressions described in the previous chapters. In turn, the orbit of the Early Bird at any time can be predicted. We shall carry out our verifications to use the first-order solution with a limited number of dominant terms in order to simplify our presentation.

The following expressions, which have been derived previously, are presented for the convenience of reference in the discussions followed.

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*The author is indebted to Dr. Victor J. Slabinski of the Communications Satellite Corporation (now at INTELSAT) for his valuable help in obtaining this information.
Inclination:  
\[ I = \tan^{-1} \left( \frac{X_1^2 + X_2^2}{2} \right)^{1/2} \]  
(7.1)

Ascending node:  
\[ \Omega = \tan^{-1} \left( - \frac{X_1}{X_2} \right) \]  
(7.2)

Argument of perigee:  
\[ \omega = \tan^{-1} \left[ \frac{X_1 X_3' + X_2 X_4'}{X_2 X_3' - X_1 X_4'} (1 + X_1^2 + X_2^2)^{1/2} \right] \]  
(7.3)

Eccentricity:  
\[ e = \frac{X_2^2}{\mu_E} \left(1 + \frac{X_1^2 + X_2^2}{X_3^2 + X_4^2} \right)^{1/2} \]  
(7.4)

Radial deviation (\( \Delta r_c \)):  
\[ \delta = \delta_0 = \frac{1}{3} \left( \frac{2k_1}{\mu E} \right)^{1/2} \left[ \frac{2k_1}{1 - k_2} \right]^{1/2} \]  
(7.5)

Drift angle (\( \tau \)):  
\[ \cos 2\tau_0 - \cos 2\tau = \frac{r_c^2}{8J_2^2 \mu E^2} \left[ \frac{\Delta r_c}{r_c} \right]^{2} + 3J_2 \frac{r_c^2}{2} \left[ \frac{\Delta r_c^0}{r_c} \right]^2 \]  
(7.6)

Drift rate (\( \dot{\tau} \)):  
\[ \dot{\tau} = - \frac{3}{2} \frac{\Delta r_c}{r_c} \]  
(7.7)

7.2. Verification by Observed Data

The available observed data of the 'dead' Early Bird Satellite from May 27, 1970 to August 15, 1973 are listed in Table VIII. The initial conditions are taken from the observed data at 1900 (Greenwich Mean Time), May 27, 1970, except for \( e \), which is selected to be 0.0007 instead of 0.000789. Because the difference results in a topocentric look angle error of only 0.01 degree, which is the accuracy of the angle measurements, this selection seems to be allowable. At the initial epoch, the positions of the Sun and Moon, the ascending node and the argument of perigee of the Moon's orbit were 66.82° (\( \tilde{\gamma}_0 \)), 2.68° (\( \tilde{\nu}_0 \)), 337.51° (\( \tilde{\iota}_M^0 \)), and 341.49° (\( \tilde{\omega}_M \)), respectively; they were obtained from the American Ephemeris and National Almanac, U.S. Government Printing Office, Washington D.C., 1970. The intensity of solar radiation pressure (\( P_r \)) was 4.5 \times 10^{-6} \text{ N/m}^2 (0.92 \times 10^{-7} \text{ lb/ft}).

By employing (7.1) and (7.2) with known \( \tilde{\gamma}_0 \) (75.433°) and \( \tilde{\iota}_M^0 \) (4.857°), \( \tilde{X}_{10} \) and \( \tilde{X}_{20} \) are obtained. After examining the magnitude of all terms in \( u_1^{(1)} \) and \( u_2^{(1)} \), shown in (4.97) and (4.98), and the additional terms due to the long-period terms in solar perturbation on the Moon's motion, it is found that the terms containing \( A_3, A_4, A_7, A_8, A_{26}, A_{29}, \) and \( A_{30} \) play a dominant role. Therefore, \( \tilde{X}_1 \) and \( \tilde{X}_2 \) can be approximated by