experimental data, the number of electrons in a vertical column of 1 cm^2 cross-section was determined both for the lower and upper regions of the F_2-layer. For the upper region this figure turned out to be twice that for the lower one. At great distances of the satellite from the observation post, beginning with 6000–8000 km, the field strength exceeded the values obtained from the equation for ideal radio transmission. This indicates that electromagnetic energy was propagated, due to formation of ionosphere waveguides, to great distances which made it possible to receive satellite radio signals at distances reaching 16,000 km.

12. SATELLITE ORBITS AND ATMOSPHERIC DENSITIES AT ALTITUDES UP TO 750 KILOMETERS OBTAINED FROM THE VANGUARD ORBIT DETERMINATION PROGRAM

JOSEPH W. SIRY

The satellites 1958 β_2 (Vanguard I) and 1958 γ (Explorer III) represent extremes from the orbit-determination standpoint. The absolute fluctuations in the mean motion were smallest for the former, and largest for the latter, among the satellites for which precision Minitrack radio observations were available. Accordingly, the orbit of the former has been determined with the greater precision. Even in the case of 1958 γ, however, the root-mean-square value of the residuals is less than twenty minutes of arc. The radial distances between adjacent arcs at the times for transferring from one arc to the next are of the same order as the residuals within the individual arcs. The results obtained with this satellite are of interest since they indicate what can be done in the way of determining the orbits of satellites having very low perigees and very high fineness ratios. Errors of less than four minutes of arc have been obtained for some of the orbital arcs of 1958 β_2 [1].

A significant measure of air density at a very high altitude was obtained from the orbital data for this satellite. In the case of 1958 β_2, the drag parameter has the value 3·25 g/cm^2, if diffuse reflexion with no accommodation is assumed. The observed rate of change of period was $3{\cdot}1 \times 10^{-4}$ minutes per day during the first three months of its lifetime. If the atmosphere over the entire orbital range is considered to be isothermal, these data imply the relation between perigee density and scale height which is indicated by the uppermost curve of Fig. 2. An assumption about scale height allows one to arrive at an estimate of the density at this altitude. Similar curves for other altitudes also appear in this figure. It is seen that the 750 km level is of particular interest. At this height any assumption as to scale height in the range from 125 to 350 km yields very nearly the same implication concerning the density. This height can thus be regarded as a pycnometric level, i.e. a level at which the density is separated relatively well from the other atmospheric parameters, and hence can be determined by means of the satellite observations on the basis of assumptions which are not very restrictive. This type of analysis has also been conducted for two other cases, corresponding to temperature gradients of 2° per kilometer, and 4° per kilometer, respectively. The resulting curves of density versus scale height are similar to those of Fig. 2. The 750 km level again has useful pycnometric properties. The atmospheric density is found to lie within about 8% of $1{\cdot}2 \times 10^{-16}$ g/cm^3 for all scale heights between 125 and 350 km and all temperature gradients from 0° K per kilometer to 4° K per kilometer. Variations of about 25% were observed in the period decrements for 1958 β_2 during the period covered by this study. Correlations with other geophysical and solar parameters are being sought in further analyses. The effect of contributions of charged particles to the drag would be to decrease the corresponding value of the total mass density [2]. Estimates based upon moderate assumptions about the charged-particle drag indicate that it may contribute perhaps 10% of the total drag effect.

An analysis of the same general type has been made for the satellites 1957 α_2 and 1958 α [1]. The results for all three satellites are shown in Fig. 3. The latitude of perigee associated with the 1958 α and 1958 β_2 observations was about 20° North. The latitude of perigee associated with the 1957 α_2 observation was about 50° North.

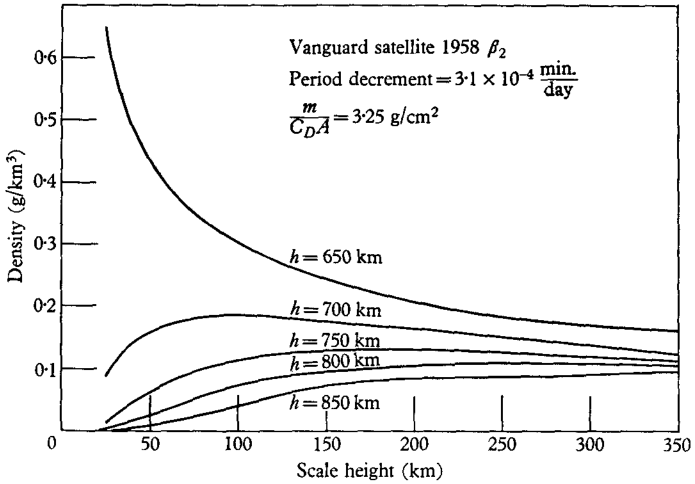

Fig. 2. Graph illustrating certain pycnometric properties of the orbit of the satellite 1958 β_2, Vanguard I. Shown are curves of density versus scale height at several altitudes as implied by the orbital data for this satellite. An isothermal atmosphere is assumed.

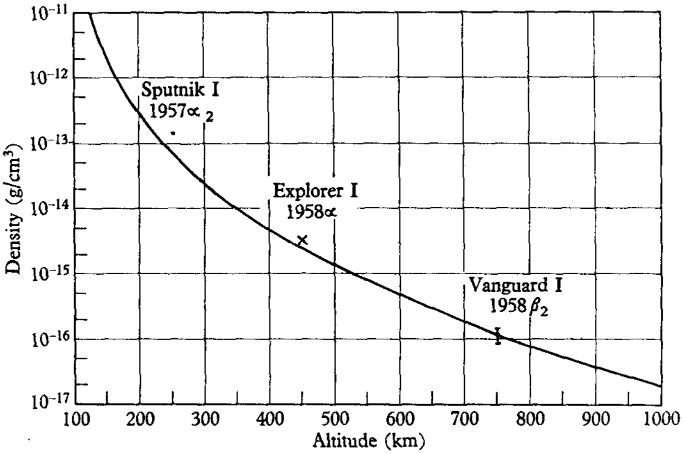

Fig. 3. Density versus altitude for an atmospheric model of the Nicolet thermal conduction type adjusted to agree with the orbital data for the satellite 1958 β_2, Vanguard I. Other satellite density values are also shown.

It was found that the 1958 β_2 orbital data imply that the reference temperature at 500 km is about 1600° K in an atmosphere of the Nicolet thermal conduction type [3]. The corresponding temperature gradient and energy flux at this level are about 2° K/km and 0·3 ergs/cm² sec, respectively. For this atmosphere the temperature and the temperature gradient at the 750 km level are about 2100° K, and 2° per kilometer, respectively. These values fall within the pycnometric region at this altitude which was described earlier. The density implied by this atmosphere at the pycnometric level of 750 km is $1{\cdot}2 \times 10^{-16}$ g/cm^3.

The atmospheric density profile which follows Nicolet's theory and is adjusted to fit the 1958 β_2 data is shown in Fig. 3. This atmospheric model is consistent with the satellite observations made at the higher altitudes in the 68°.6 latitude belt centered on the equator.

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13. ON BRIGHTNESS VARIATIONS OF ARTIFICIAL SATELLITES

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It is well known that the brightness of artificial satellites is variable.

Regular observations enable us to establish:

1. the rotation period;
2. the variation of the period;
3. the direction of the axis of the satellite;
4. the variations of this direction as a result of precession.

Many brightness observations of the second and third satellites have been obtained by Soviet astronomers. The preliminary results are as follows:

(1) Observations of the second sputnik were made at many stations, especially in Odessa, Gorky, and Leningrad. The treatment, by V. Grigorevsky, of a part of these observations has shown that the brightness variations resemble those of a diffuse scattering body. A large number of light-curves were obtained. Changes in the distance of the sputnik from the observer, as well as the effect of phase angle, were taken into account. After an exhaustive examination of these light-curves we expect to determine the direction of the axis of rotation.

The formula for the period of rotation is:

$$\text{J.D. of maxima} = 2\,436\,187{\cdot}654\,21 + 0^{\mathrm{d}}{\cdot}001\,208\,907\,56\,E + 0^{\mathrm{d}}{\cdot}000\,178\,9\,(E \times 10^{-4})^2.$$

(2) The rocket of the third satellite changes its brightness very rapidly and with a large amplitude. Many times of light-maxima were obtained by us. These times are represented by the formula:

Times of maxima $= 1958$ July $23.\,032\,135 + 0^{\mathrm{d}}{\cdot}000\,101\,189\,2\,E + 0{\cdot}000\,068\,7 \times 10^{-8}\,E^2$. During each passage of the rocket there are some definite deviations from the formula

$$M = M_0 + P'.E,$$

where P' is a temporary value of the period. These deviations enable us to determine the direction of the axis.

We suppose that:

(*a*) the shape of the rocket is cylindrical;
(*b*) the axis of rotation is perpendicular to the cylinder axis;
(*c*) the rocket body does not scatter solar light, but reflects it.