X-612-67-355

NASA TM X- 55847

EARLY RESULTS FROM THE MAGNETIC FIELD EXPERIMENT ON LUNAR EXPLORER 35

N. F. NESS
K. W. BEHANNON
C. S. SCEARCE
S. C. CANTERANO

JULY 1967

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

EARLY RESULTS FROM THE MAGNETIC FIELD EXPERIMENT ON LUNAR EXPLORER 35

by

N. F. Ness
K. W. Behannon
C. S. Scearce
S. C. Cantarano*

July 1967

---

*Now at the University of Rome, Rome, Italy

Abstract

Explorer 35 was injected into a selenocentric orbit on July 22, 1967. Analysis of measurements near pericynthion (2500 Km) while the moon is within the geomagnetic tail suggest that the moon is not magnetized and that its moment is less than 4 x 10^{20} cgs. units (10^{-5} of the earth). Rapid diffusion of interplanetary magnetic field lines through the lunar body limits the average electrical conductivity to a maximum value of 10^{-5} mhos/meter. Thus capture of interplanetary magnetic field lines by the moon and formation of a lunar magnetosphere as theorized by Gold is not substantiated. A lunar bow shock wave has not yet been observed when the moon is located in the interplanetary medium or the magnetosheath of the earth.

Introduction

The NASA Explorer 35 was launched from the Eastern Test Range Cape Kennedy, Florida on July 19, 1967 at 14:19:02 UT. The principal objective was to place the spin stabilized IMP type spacecraft into a lunar orbit to investigate the magnetic field of the moon and the interaction of the solar wind with the lunar body. The secondary objective is associated with the orbit of the moon which permits monitoring of the interplanetary medium and the earth's magnetic tail once each lunar month. This is possible only if the influence of the moon is negligible during a portion of the satellite orbit.

The transfer trajectory was very close to nominal and is shown projected on the ecliptic plane in Figure 1. Analysis in real time of range and range rate tracking data indicated that a successful lunar orbit was possible with injection times between 66.5 to 68.5 hours after liftoff. The restrictions of the launch vehicle on spacecraft weight (104 Kg) precluded use of a midcourse maneuver capability. Thus the range of orbital parameters possible depended upon time of firing the retro motor to anchor the spacecraft into a stable lunar orbit. Restrictions of technical factors related to the performance of the spacecraft power system required considering orbits with periods approximately 12 hours or greater. Without reorientation of the spin axis, parallel to the retro thrust vector, this would have limited lunar orbits to those of moderate eccentricity with a minimum pericynthion of 3,000 Km.

The interaction of the super Alfvénic solar wind with the moon might be expected to produce a lunar bow shock wave at a distance from the lunar surface of 500 to 800 Km. Hence it was desirable to decrease the pericynthion distance in order to perform measurements near the stagnation point of plasma flow close to the moon. It was necessary to utilize the spacecraft attitude control system so that the two requirements on satellite orbit parameters, scientific and technical, could be satisfied. A successful reorientation of the satellite spin axis of 5.5° was performed on July 20 between 2000-2200 UT. The selected time to fire the fourth stage was chosen as 67.0 hours after lift-off which statistically guaranteed a lunar orbit with a dynamical lifetime in excess of several years, a pericynthion less than 2600 Km. and an orbital period of approximately 12 hours. Explorer 35 was injected into a captured lunar orbit on July 22 at 09:19:25. The orbital parameters obtained from analysis of early tracking data indicate an apocynthion of $\sim$ 9400 Km, pericythion $\sim$ 2500 Km, eccentricity $\sim$ 0.6, and an orbital period of 11.5 hrs. (See Figure 2). The orbital plane is inclined at 166° to the ecliptic plane thus leading to a retro-grade orbit when compared with planetary motions about the sun. The inital apocynthion-moon-sun angle, ϕ_{SSE} is 304° east of the sun as measured in selenocentric solar ecliptic coordinates (X axis directed from moon to sun, Z axis from moon to north ecliptic pole, Y axis forming righthanded coordinate system). This angle will decrease by approximately 1.1° /day due to the heliocentric motion of the earth about the sun and the perturbations by the gravitational fields of the sun and earth.

Subsequent to the lunar orbit injection and following sufficient orbital tracking to establish the stability of the orbital parameters, a final reorientation maneuver was conducted. The objective was to reorient the spin axis to be perpendicular to the plane of the ecliptic for technical and scientific reasons. A fixed orientation of the spin axis relative to the spacecraft-sun line eliminates the seasonal effect of variations in temperatures and solar panel power output associated with non-orthogonality. A more important consideration relates to the angular acceptance cone of certain instruments on the spacecraft such as the plasma probe whose view is perpendicular to the spin axis in the equatorial plane of the spacecraft with a full angle of $\sim 60^{\circ}$. This final reorientation maneuver would thus permit continuous monitoring of the solar plasma flux with a constant viewing angle at the optimum aspect for the plasma probe.

The final reorientation was accomplished in two phases, the first occurring between 2106 July 25 - 0143 July 26 and the second between 1521 - 1722 July 26. A total angular excursion of 101° placed the spin axis directed within a few degrees of the south ecliptic pole (RA = 9°, DEC = 66.5°). Throughout these attitude maneuvers the spacecraft spin rate decreased slightly due to the loss of angular momentum as the gas jets were activated. The final spin rate of 26.1 RPM should remain constant since the solar radiation pressure spin-up and spin-down, characteristic of previous spacecraft with solar paddles in the Explorer series, is avoided with the 90° aspect to the sun.

Investigation of the magnetic field environment of the moon has been conducted by the USSR with its space probe Luna 2 (Dolginov et al., 1961) and Luna 10 which orbited the moon with intermittent data transmissions for two months beginning in April 1966 (Dolginov et al., 1966; Zuzgov et al., 1966). From Luna 2 it was concluded that with the ± 50 gamma accuracy of the instrument there was no detectable lunar magnetic field. This led to an upper estimate of the magnetic moment of the moon=10^{-4} that of the earth (8.1 x 10^{25} cgs. units). The possible detection of the magnetohydrodynamic wake of the moon, observed by IMP 1 in 1963, was reported by Ness (1965a).

Mapping of the distant geomagnetic tail by IMP 1 (Ness, 1965b) and more recently Explorer 33 (Behannon, 1967; Ness et al., 1967) has shown the extension of the geomagnetic field forming a magnetic tail pointed in the antisolar direction extending beyond the orbit of the moon. A well defined imbedded field reversal region referred to as a neutral sheet has also been detected and analyzed (Speiser and Ness, 1967). In addition the detection of the plasma sheet associated with this field reversal region has been reported by the Vela 3 experiment of Bame et al., (1967).

Measurements obtained on the Luna 10 spacecraft reportedly failed to detect the earth's magnetic tail within 2 days of full moon, when it would be expected, and a reinterpretation of the results has been presented by Ness (1967). Dolginov et al.,(1967) have suggested, however, that the moon possesses a magnetosphere and thus even when it is within the geomagnetic tail, lunar orbiting spacecraft do not detect the geomagnetic tail field.

This paper presents early results and preliminary interpretations of data obtained with the NASA-GSFC tri-axial fluxgate magnetometer experiment during the first 12 orbits of the moon during 22-27 July 1967. The position of the moon changed from being imbedded in the earth's magnetic tail thru transversal of the earth's magnetosheath and finally passage into the interplanetary medium. The data presented covers the time interval from the transfer trajectory July 20 through the third lunar orbit on July 23.

Instrument and Data Presentation

The NASA-GSFC magnetic field experiment on Explorer 35 is similar to that instrumented for the Explorer 33 spacecraft (Behannon, 1967). Briefly, the fluxgate sensor is mounted at the end of a boom 2.2 meters from the spin axis to reduce contamination by magnetic fields associated with the spacecraft to less than 0.25γ. A combination of the intrinsic spin of the spacecraft and a flipper device permits calibration of the zero levels of the three sensors once every 24 hours. At this early date the zero levels are known to an accuracy of approximately ± 0.3γ. Subsequent analysis and processing of improved quality production data tapes, as opposed to quick look data tapes, will reduce this uncertainty.

A new feature of the Explorer 35 instrument is the incorporation of an automatic range switch which changes the sensitivity on the basis of inflight measurements. The two ranges selected were ± 24γ and ± 64γ on each axis, with a sensitivity of ± 0.1 and ± 0.25 gamma, respectively, for the 8 bit quantization employed. At intervals of 81.82 seconds the instrument determines whether or not the preceding 16 measurements (at 5.11 second intervals) permitted or required a change in the range. A separate flag bit is telemetered once each sequence to provide unique identification of the correct scale factor to apply in converting the engineering units to physical quantities. This range switch feature improves the sensitivity of the experiment by a factor of 2.5 when compared to the previous Explorer 33 experiment. The range switch changed scale from high range to low range at a geocentric radial distance of

18 R_E (~0010 UT July 20) during the outbound traversal of the magnetotail and has remained in the low range subsequently. The data presented herein are thus made with a sensitivity of ± 0.1γ.

The magnetic field data to be presented and discussed in this initial report represent averages of the magnetic field components computed over individual sequences of 81.8 seconds. The data is presented in either a geocentric or selenocentric coordinate system. Since the moon-earth distance is such a small fraction of the earth-sun distance the two coordinate systems are identical for discussing magnetic field directions. Component averages of the observation are used to reconstruct a vector magnetic field magnitude and direction. In addition a computation of the average RMS component deviation is obtained by linearly averaging the three orthogonal component RMS deviations obtained in computing the component averages. This parameter is diagnostic in indicating regions in which the magnetic field fluctuates on time scales ~0.2 - 80 seconds.

At this early date it has not been possible to subject all of the data to a detailed critical analysis and eliminate spurious data points. However, such refined analysis is not expected to alter the principal conclusions which have been reached from this initial analysis. The reader will readily identify such data points in the presentation particularly when the very steady magnetic fields in the earth's magnetic tail and in the interplanetary medium are being measured. Data obtained when the moon and hence Explorer 35 is imbedded within the neutral sheet region of the earth's magnetic tail or the magnetosheath presents a more difficult task because of the ambient field fluctuations characteristic of these regions.

Observations

During the early portion of the transfer trajectory, shown in Figure 1, the measured magnetic field direction approached the sun-earth line characteristic of the geomagnetic tail at distances greater than 15 R_E. The data for July 20, 1967 following the range change to the instruments most sensitive scale is shown in Figure 3. Here the field direction closely parallels the earth-sun line ($\theta = 0^o$, $\phi = 180^o$) and is very steady. In addition the sense of the field away from the sun indicates that Explorer 35 is located within the lower portion of the geomagnetic tail. Field magnitudes observed, between 15 - 25γ, are in excellent agreement with previous results obtained with other spacecraft mapping this region of space. Spurious data points are evident because of their large RMS values.

As the satellite continued outbound in its transfer trajectory the field direction remained essentially constant. Data for July 21st is presented in Figure 4 and shows a continuation of the characteristic tail field geometry at radial distances of 40 to 55 R_E. Gaps in the data are observed, generally of 10 to 20 minutes duration and correspond to intervals when the range and range rate system is exercised and transmission of scientific data is temporarily suspended.

The general features of the observations are similar to those reported for July 20 with characteristic time variations and increases in fluctuations corresponding either to identifiable "island" events (Anderson and Ness, 1966) or poor quality data as indicated by anomalously large RMS values and inconsistent variations of field magnitude and direction. At approximately 1200 UT on July 21 it is noted that the field magnitude decreases frequently to relatively small values. At this time the spacecraft was approximately 0.5 R_E below the solar magnetospheric equatorial plane and probably close to the neutral sheet.

Data for July 22 is presented in Figure 5 which includes injection of Explorer 35 into lunar orbit and the first 1-½ lunar orbits. Generally the magnetic field during this time interval is observed to be similar to that previously detected characteristic of the southern portion or lower half of the geomagnetic tail, $\theta \sim 0^o$; $\phi \sim 180^o$. At these great distances from the earth .60 R_E, the field magnitude of 10 - 12^γ appears to be slightly larger than the average of 8^γ observed by Explorer 33 (Behannon, 1967). Following injection as shown in Figure 2, the satellite is occultated by the moon for telemetry transmissions to earth. Subsequently, it is seen in Figure 5 that the data obtained in close lunar orbit after pericynthion is essentially unchanged from that obtained prior to occultation and during the transfer trajectory. The field magnitude remains constant and the direction ($\theta \sim 0^o$, $\phi = 180^o$) does not change. The fluctuations observed in the magnitude and direction after 1700 UT July 22 are interpreted to represent immersion of both the moon and Explorer 35 in the earth's neutral sheet region in the geomagnetic tail. Generally the data correspond remarkably well to observations obtained one year earlier on Explorer 33 in studying the geomagnetic tail and neutral sheet regions at and beyond the moon's orbital distance. There appear to be no identifiable changes associated with proximity to the moon since there are no coherent variations of the data with orbital position or distance with respect to the moon. This sets an upper limit of a few gammas for the lunar magnetic field at pericynthion (1.4 R_M).

Orbits 2 and 3 are continued in Figure 6 on July 23, 1967. Here the character of the data is notably different than that on 20-22 July. The direction of the field is observed to generally be inclined at a large angle to the ecliptic plane and in a sense towards the sun with large amplitude variations. In addition the magnitude of the field is much weaker, being 7 - 10^{γ} throughout most of this time. Higher frequency fluctuations are detected in the RMS deviations and are a factor of 2 to 5 larger than observed previously in the tail at these distances (Behannon,1967). The data is very characteristic of the earth's magnetosheath region in which the magnetic field of interplanetary origin is convected around the magnetosphere by the supersonic solar wind. An interesting feature of these data is that again there appears to be nothing uniquely discernible in the data which can be associated with the orbiting of the moon. It is to be noted that the RF occultations of the satellite by the moon are not coincident with optical shadows so that for short periods of time the spacecraft is battery powered and transmitting measurements obtained within the lunar penumbra and umbra.

The interpretation of certain of the fluctuations observed in the data presented in this early report reference the proximity of the satellite to the neutral sheet imbedded in the earth's magnetic tail. A plot of the variation of the perpendicular distance of the moon and Explorer 35 from the solar magnetospheric equatorial plane is presented in Figure 7. Here it is noted that the satellite is close to the theoretical neutral sheet at 1200 on July 21 and also 1200 July 22. Since the measurements are obtained shortly after summer solstice the inclination of the geomagnetic dipole axis to the solar wind velocity changes the relative position of the neutral sheet by only a small amount. It is known that on average during the northern hemisphere summer the real neutral sheet is located several earth radii above the theoretical position defined by the solar magnetospheric equatorial plane (Ness, 1967). At the time the satellite appears to pass into the magnetosheath, between 2130 - 2400 UT July 22, the moon is located $\sim 18\ R_E$ from the sun-earth line. This is in good agreement with previous measurements of the diameter of the geomagnetic tail, 40 R_E, by Explorer 33 at $X_{SE} = -50$ to $-70\ R_E$ in the solar magnetospheric equatorial plane.

Interpretation

It appears from the intial inspection of the data obtained when the moon and the Explorer 35 are imbedded in the earth's magnetic tail that there is no detectable lunar magnetic field at the pericythion distance of 2500 kilometers. Temporal variations associated with the proximity to the neutral sheet limit the magnitude which can be set to approximately a few gamma. On the assumption that the moon possesses a simple dipole magnetic field a conservative upper limit to the affective magnetic moment can be set. The value obtained is 4×10^{20} cgs. units and is a factor of 10 less than that set by the earlier Russian measurements obtained from Luna 2. This analysis of Explorer 35 data indicates that the intrinsic lunar magnetic field on the surface of the moon is approximately 8γ or less. Possible local variations of limited spatial extent could lead to larger surface magnetic fields observable during the four day interval centered on full moon when it is imbedded in the earth' magnetic tail. This absence of any intrinsic lunar magnetic field obviously precludes the existence of a trapped radiation environment of the moon.

From the observations obtained when the moon is immersed within the magnetosheath it appears that there is no obvious disturbance associated with the moon. This indicates that in the earth's magnetosheath there is no lunar bow shock wave developed around the lunar body. This further suggests that the important feature of a scale factor difference of 50 to 1 between the earth's magnetosphere and the moon is significant in determining the interaction characteristic of the solar wind with the moon. Previously it had been questioned by Ness (1965) whether or not a shock wave would always develop about the moon under varying solar wind conditions when imbedded in the interplanetary medium. It should be noted however, at this early date that the limited analyses performed for the few orbits of data available may not be sufficient to reveal the presence of a relatively low mach shock which encompasses the moon when it is in the earth's magnetosheath. This is in distinction to the relatively high mach shock which develops around the earth's magnetosphere at all times regardless of the interplanetary medium conditions. Analysis of data from later orbits when the moon is located within the interplanetary medium do not reveal the presence of any disturbance clearly associated with the moon which appears to be a bow shock wave.

The absence of any detectable change in the field magnitude associated with the moon when it is immersed in the magnetosheath and when the satellite is behind the moon indicates that the diffusion of interplanetary field lines through the moon is rapid. This rate of leakage of interplanetary field lines, when compared with the convective solar wind velocities permits an upper limit to be set on the effective electrical conductivity of the lunar body. In figure 8 a variation of the lunar body diffusion time is presented for effective conductivities of material which are typically thought to form the moon. The existence of a very small core of highly conducting material would only marginally affect the convection of interplanetary field lines through the moon and cannot be rejected at this early date. However, it can reasonably be concluded that the diffusion time of interplanetary field lines must be on the order of the convection time of the solar plasma pass the moon since there is no noticable disturbance of the magnetic field in the lee of the moon. Since the diameter of the moon is 3476 Km. an assumed plasma velocity of 300 Km/sec. yields a time scale of 12 seconds. This correspondingly yields an upper conductivity limit of 10^{-5} mhos/meter assuming the magnetic permeability of the moon to be that of free space. In a computation of the diffusion time the μ and σ appear as a product so that the diagram in figure 8 shows the abscissa as the product of the ratio of the real magnetic permeability of the moon to free space times conductivity as the variable parameter. The distribution of electrical conductivity within the moon is unknown, but the average value obtained can be related to the average thermal regime of the lunar body. It is well known that the principal factor affecting low frequency conduction of electrical current in typical earth materials below the crust depends principally upon temperature and only to second order on pressure variations. Thus an accurate measure of the electrical conductivity of the moon (and its composition) would permit a prediction of the internal temperature of the moon. From the limited analyses of data performed thus far, setting an upper limit of 10^{-5} mhos/meter and assuming a temperature dependence similar to periclase and olivine (Hamilton, 1963) yields a maximum average temperature of the moon of less than 1000°.

Conclusions

Initial analyses of early results obtained from the Explorer 35 magnetic field experiment of the NASA-GSFC indicates the absence of an intrinsic lunar magnetic field. These observations are performed when the moon is imbedded in the earth's magnetic tail and thus in a most favorable condition for detection of any ambient lunar magnetism. An upper limit of 4×10^{20} cgs. units is obtained which yields a maximum surface magnetic field of approximately 8γ.

The apparent absence of a detectable bow shock wave encompassing the moon in the magnetosheath indicates that the difference in size of the lunar body and the earth's magnetosphere is important in considering the interaction of the solar plasma with the moon. A characteristic scale length usually chosen is a proton Larmor radius which is approximately 500 Km. This is of the order of the standoff distance from the lunar surface and hence the solar wind may not be able to develop a fluid flow type bow shock wave.

The magnetic field observations suggest that the moon does not accumulate interplanetary magnetic field lines because of its low conductivity. This sets an upper limit of 10^{-5} mhos/m for an effective average electrical conductivity of the moon A lunar magnetosphere, as proposed by Gold (1966), does not appear to be formed.

Dolginov et al., (1967) suggest that the moon possesses a magnetosphere based upon their experimental observations which report that the magnetic field was observed to always lie between $24\text{-}40\gamma$ regardless of the position of the satellite relative to the moon and the earth. The early experimental results from Explorer 35 do not confirm such large fields reported in the vicinity of the moon. Although Luna 10 is in a closer orbit (apocynthion = 2700 Km, pericynthion= 2100 Km) it is difficult to reconcile the experimental data of Luna 10 with those from Explorer 35.

The low conductivity inferred from the absence of a lunar magnetosphere formed by accreted interplanetary field precludes a moon whose interior is very hot. The suggestion from these data is that the moon is now cold with a average temperature less than 1,000°K. A similar conclusion has been reached by MacDonald (1963) from a study of the possible thermal history and present figure of the moon. If the moon were of uniform composition similar to chondritic meteorites then the major fraction of the interior would be at very high temperature and unable to support the non-equilibrium figure observed. The alternative is either a non-chondritic composition or a concentration of the heat sources near the lunar surface. The precise analysis of an extended suite of observations will provide more definitive answers to the question of the effective electrical conductivity of the moon and its thermal regime.

These early results reflect the initial interpretations of data only recently obtained. As better quality data are received and more extensive analyses are performed, it is anticipated that the conservative estimates on lunar magnetism and electrical conductivity can be improved. The new and interesting question which these measurements raise is the true nature of the solar wind flow around the moon and the formation of a lunar wake. An answer to this question, both experimentally and theoretically, will also help to assess the previous report of a possible magnetohydrodynamic wake of the moon by Ness (1965a).

Acknowledgements

It is our pleasure to acknowledge the support of the Goddard Space Flight Center in the conduct of this experiment and the AIMP Project Manager, Mr. Paul Marcotte and his staff in carrying out this mission. The fluxgate magnetometer sensor was manufactured by Schonstedt Instrument Company, Silver Spring, Maryland. The instrument electronics for digital conversion and range switching logic were designed and fabricated at GSFC. We appreciate the support of Mr. Herbert Haney and Mr. William Mish of GSFC in the rapid analysis of this data. Discussions of these preliminary results with Drs. H. E. Taylor and Y. C. Whang are appreciated.

FIGURE CAPTIONS

Figure 1 Projection of the transfer trajectory of Explorer 35, the orbits of the moon and Explorer 33 on the ecliptic plane between July 19-27, 1967. Average position of the earth's magnetic tail and bow shock wave are included for reference.

Figure 2 Projection on ecliptic plane in selenocentric coordinates of injection and first orbit of moon by Explorer 35.

Figure 3 Magnetic field data obtained by NASA-GSFC experiment on 20 July 1967 during Explorer 35 transfer trajectory phase in geomagnetic tail. Geocentric solar ecliptic coordinates are shown at the bottom.

Figure 4 Magnetic field data obtained by NASA-GSFC experiment on 21 July 1967 during Explorer 35 transfer trajectory phase in geomagnetic tail. Geocentric solar ecliptic coordinates are shown at the bottom.

Figure 5 Magnetic field data obtained by NASA-GSFC experiment on 22 July 1967 during Explorer 35 transfer and lunar orbit phases in geomagnetic tail. The injection of the spacecraft is indicated as are orbital apocynthion (A) and pericythion (P) and telemetry transmission occultations by the lunar body (cross hatched region).

Figure 6 Magnetic field data obtained by NASA-GSFC experiment on 23 July 1967 during Explorer 35 lunar orbit phase in geomagnetic tail. These data include orbits 2 and 3 of the moon when the moon is imbedded within the magnetosheath of the earth.

Figure 7 Variation of the distance (Z_{SM}) to the solar magnetospheric equatorial plane ($Z_{SM} = 0$) as measured in R_E during the time interval 19-23 July 1967 when Explorer 35 and the moon were immersed within the geomagnetic tail. Injection into lunar orbit is indicated and observed in the merging of the positions as measured in geocentric coordinates.

Figure 8 Theoretical lunar diffusion time as function of effective electrical conductivity. The range of time constants, τ_1 and τ_2, corresponds to the different scale lengths assumed of either lunar radius (R_M) or lunar diameter (D_M).

References

Anderson, K. A. and N. F. Ness, Correlation of Magnetic Fields and Energetic Electrons on the IMP-1 Satellite, Journal of Geophysical Research 71, 3705-3727, 1966.

Bame, S. J., J. R. Asbridge, H. E. Felthauser, E. W. Hones and I. B. Strong, Characteristics of the Plasma Sheet in the Earth's Magnetotail, Journal of Geophysical Research 72, 113-129, 1967.

Behannon, K. W., Mapping of the Earth's Bow Shock and Magnetic Tail by Explorer 33, NASA-GSFC preprint, X 612-67-344, 1967.

Dolginov, S. H., E. G. Eroshenko, L. N. Zhugov, N. V. Pushkov and L. O. Tynrmina, Investigation of the Magnetic Field of the Moon, Geomagnetism and Aeronomy, 1, 21-29, 1961.

Dolginov, Sh. Sh., E. G. Yeroshenko. L. H. Zhuzgov and N. V. Pushkov, Measurements of the Magnetic Field in the Vicinity of the Moon on the AMS Luna 10, Doklady A. N. SSSR, 170, 574-577, 1966.

Dolginov, Sh. Sh., E. G. Yeroshenko, L. N. Zhuzgov and I. A. Zhulin, Possible Interpretation of the Results of Measurements in the Near Lunar Satellite AMS Luna 10, Geomagnetism and Aeronomy, 7, 436-441, 1967. (In Russian).

Gold, T., The Magnetosphere of the Moon, in The Solar Wind ed. by R. J. Mackin, Jr. and N. Neugebauer, pp. 381-392, Pergaman Press, N.Y. 1966.

Hamilton, Robert M., Temperature Variation at Constant Pressures of the Electrical Conductivity of Periclase and Olivine, J. Geophys. Res., 70, 5679-5692, 1965.

MacDonald, G. J. F., Internal Consitition of the Inner Planets and the Moon, Space Science Research, 2, 473-577, 1963.

Ness, N. F., The Magnetohydrodynamic Wake of the Moon, Journal of Geophysical Research, 70, 517-534, 1965.

Ness, N. F., The Earth's Magnetic Tail, Journal of Geophysical Research, 70, 2989-3005, 1965.

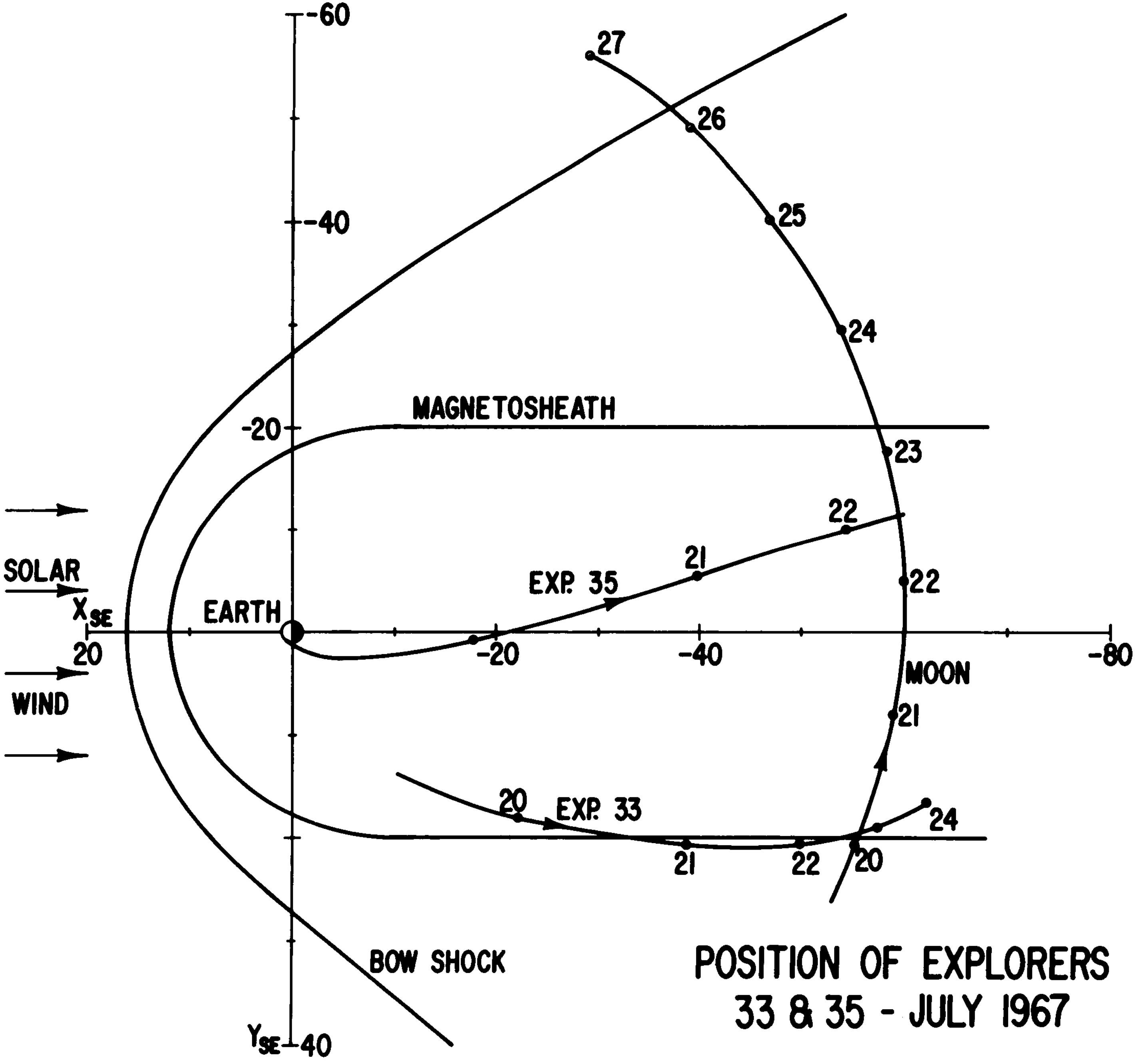
Ness, N. F., K. W. Behannon, S. C. Cantarano and C. S. Scearce, Observations of the Earth's Magnetic Tail and Neutral Sheet at 510,000 KM by Explorer 33, Journal of Geophysical Research, 72, 927-934, 1967.

Ness, N. F., Remarks on the Interpretation of Luna 10 Magnetometer Results, Geomagnetism and Aeronomy, 7, 431-435, 1967. (In Russian).

Ness, N. F., Observations of the Solar Wind Interaction with the Geomagnetic Field: Conditions Quiet in Solar Terrestrial Physics, Chapter III, edited by Newman and King Academic Press, 1967.

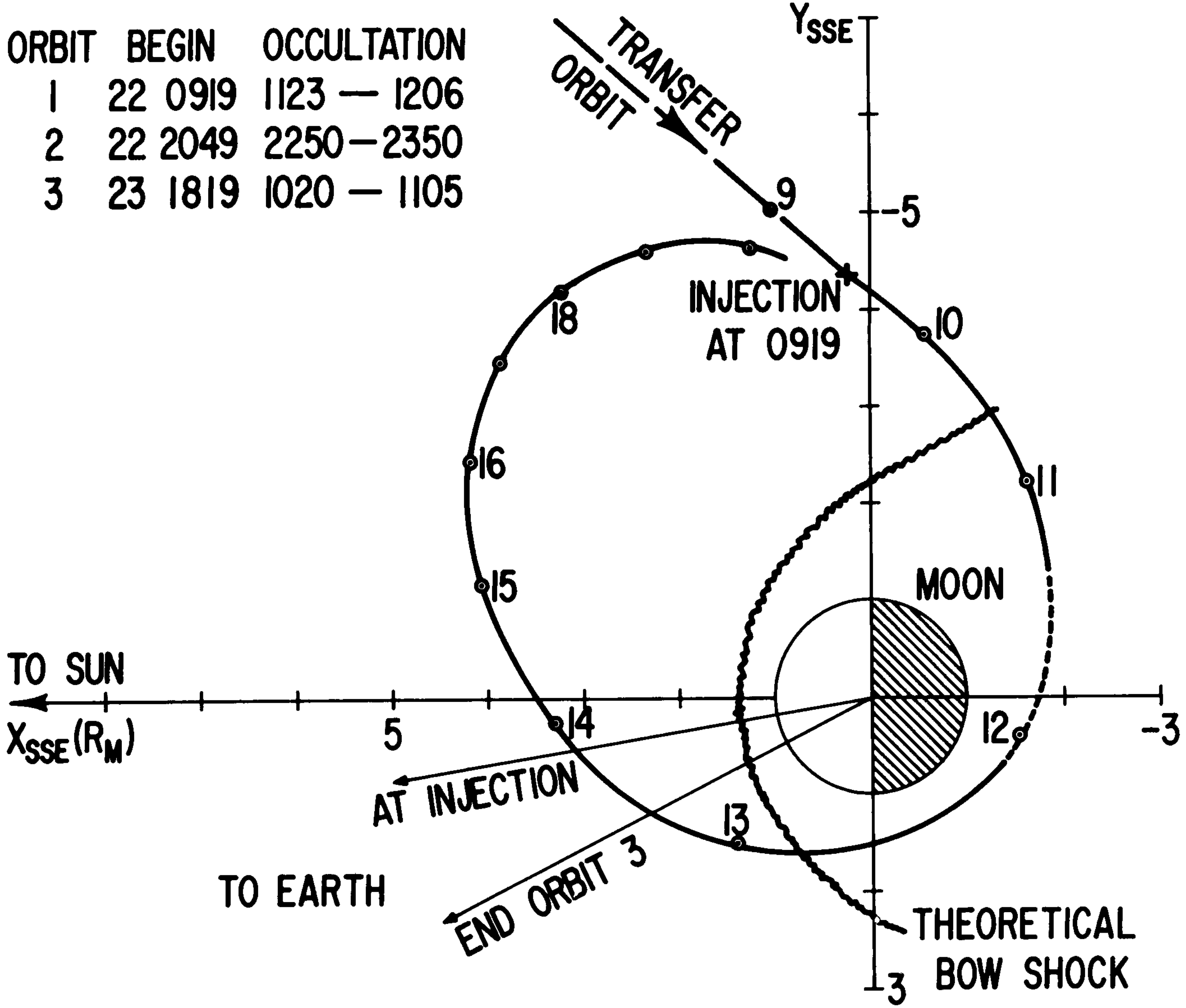
Speiser, T. W. and N. F. Ness, The Neutral Sheet in the Geomagnetic Tail: Its Motion, Equivalent Currents and Field Line Reconnection Through It, Journal of Geophysical Research, 72, 131-141, 1967.

Zhuzgov, L. N., Sh. Sh. Dolginov, E. G. Yeroshenko, Investigation of the Magnetic Field from the AMS Luna 10, Cosmic Investigations, 4, 880-899, 1966.



POSITION OF EXPLORERS
33 & 35 - JULY 1967

FIGURE 1



ORBIT	BEGIN	OCCULTATION
1	22 0919	1123 — 1206
2	22 2049	2250—2350
3	23 1819	1020 — 1105

EXPLORER 35 SELENOCENTRIC COORDINATES JULY 1967

FIGURE 2

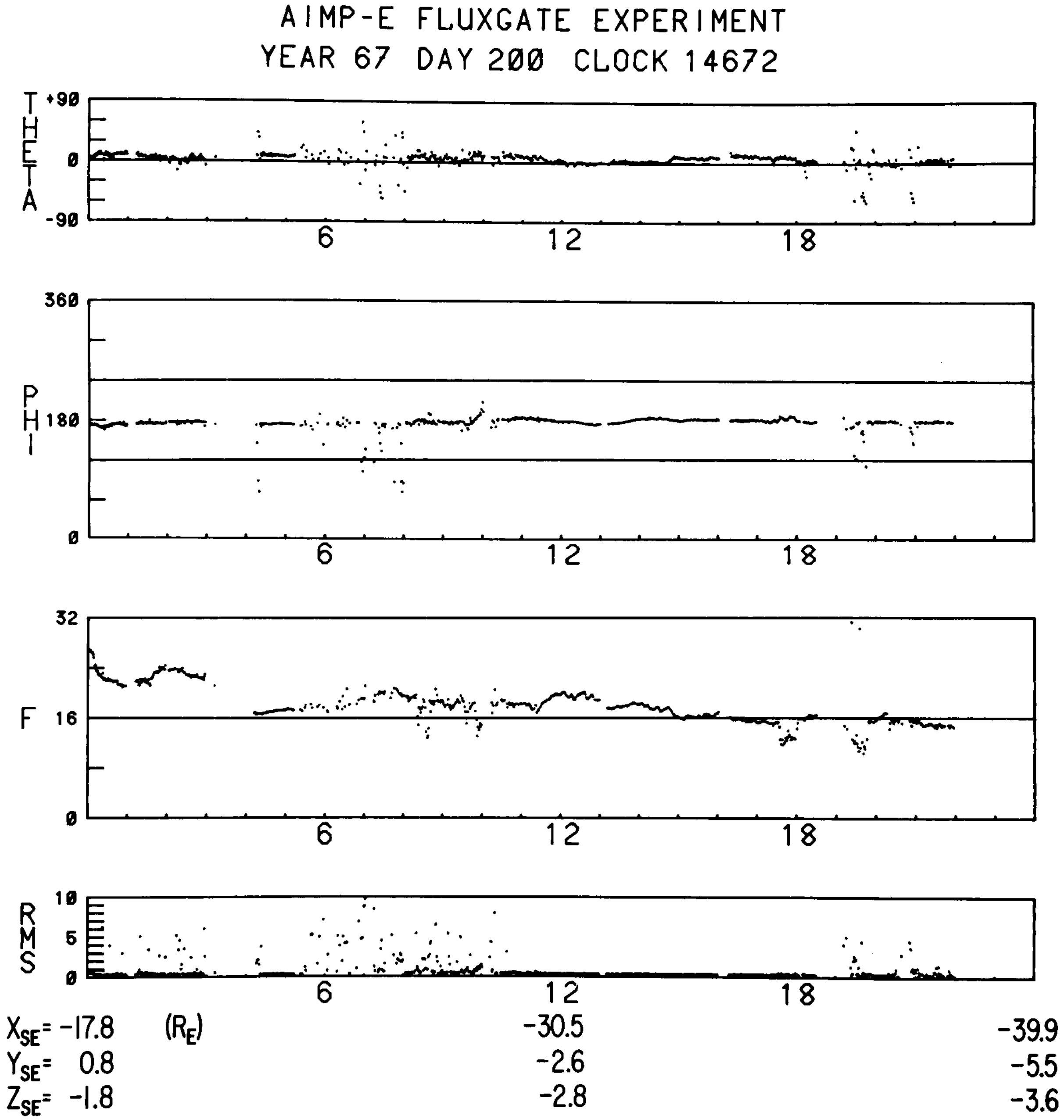

AIMP-E FLUXGATE EXPERIMENT
YEAR 67 DAY 200 CLOCK 14672
THETA
+90
0
-90
PHI
360
180
0
F
32
16
0
RMS
10
5
0
6
12
18
X_{SE}= -17.8 (R_E)
Y_{SE}= 0.8
Z_{SE}= -1.8
-30.5
-2.6
-2.8
-39.9
-5.5
-3.6

FIGURE 3

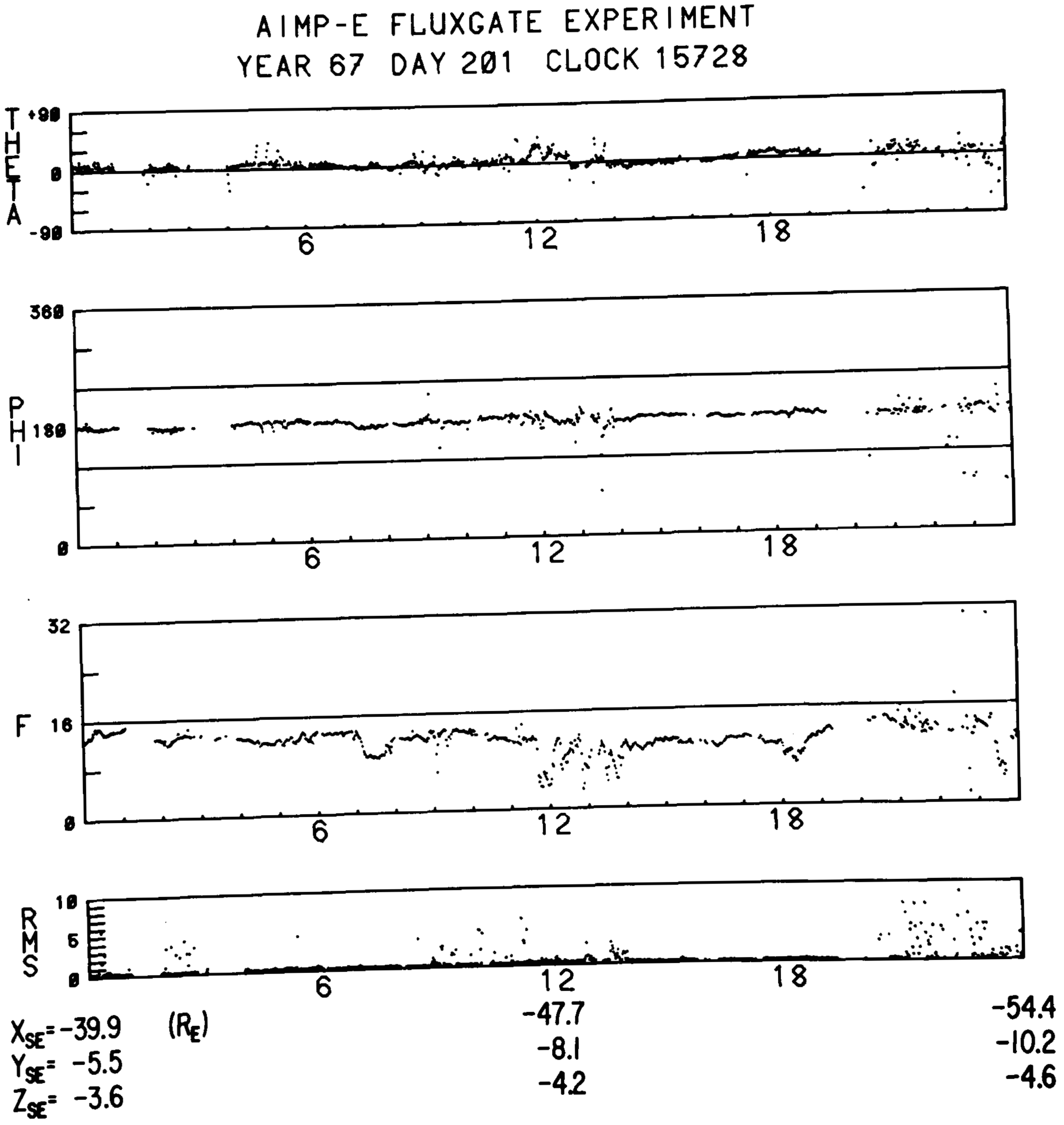

AIMP-E FLUXGATE EXPERIMENT
YEAR 67 DAY 201 CLOCK 15728
THETA
+90
0
-90
PHI
360
180
0
F
32
16
0
RMS
10
5
0
6
12
18
X_{SE}= -39.9
Y_{SE}= -5.5
Z_{SE}= -3.6
(R_E)
-47.7
-8.1
-4.2
-54.4
-10.2
-4.6

FIGURE 4

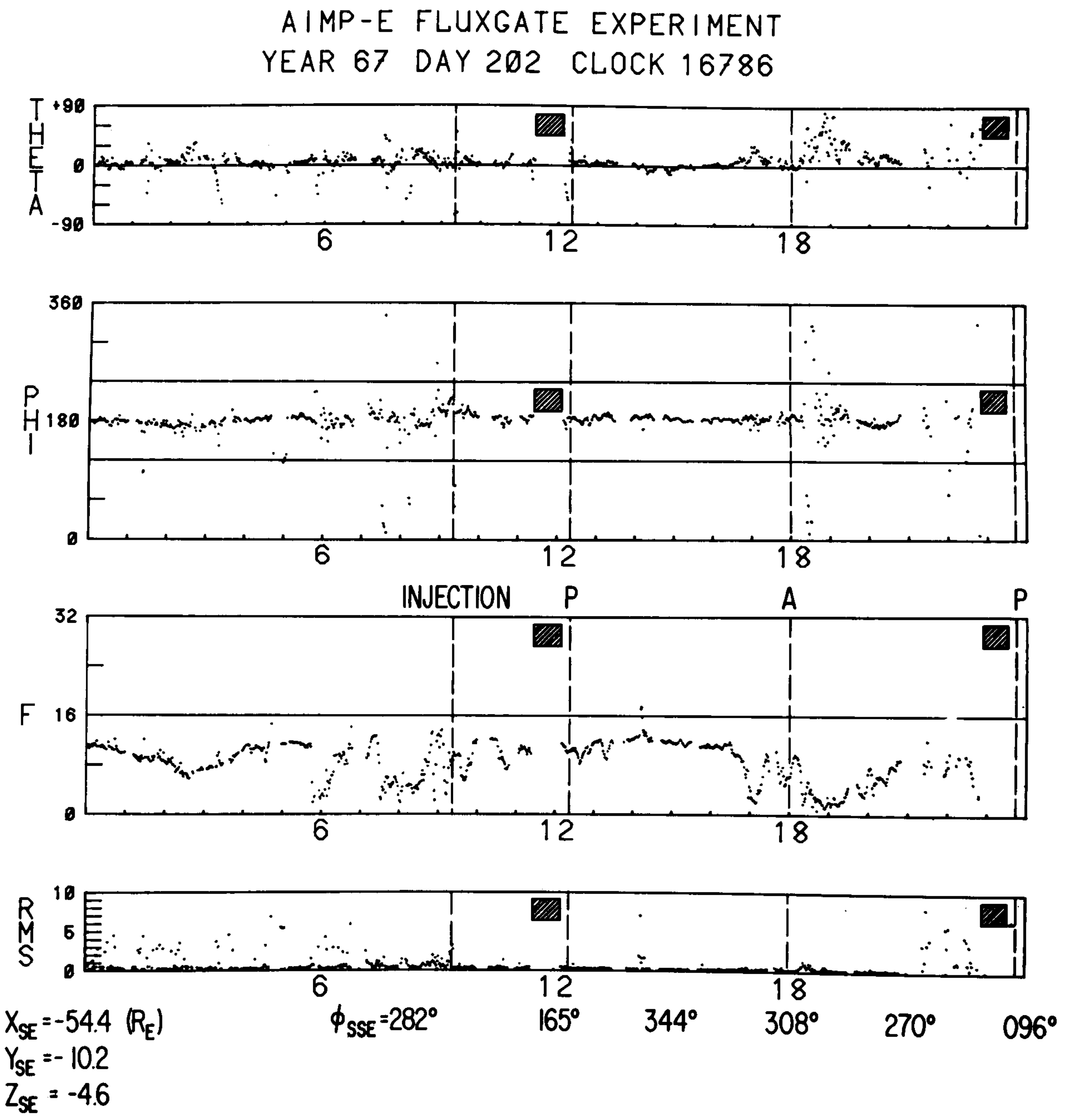

AIMP-E FLUXGATE EXPERIMENT
YEAR 67 DAY 202 CLOCK 16786
THETA
+90
0
-90
PHI
360
180
0
INJECTION
P
A
P
F
32
16
0
RMS
10
5
0
6
12
18
X_{SE}=-54.4 (R_E)
Y_{SE}=-10.2
Z_{SE}=-4.6
ϕ_{SSE}=282°
165°
344°
308°
270°
096°

FIGURE 5

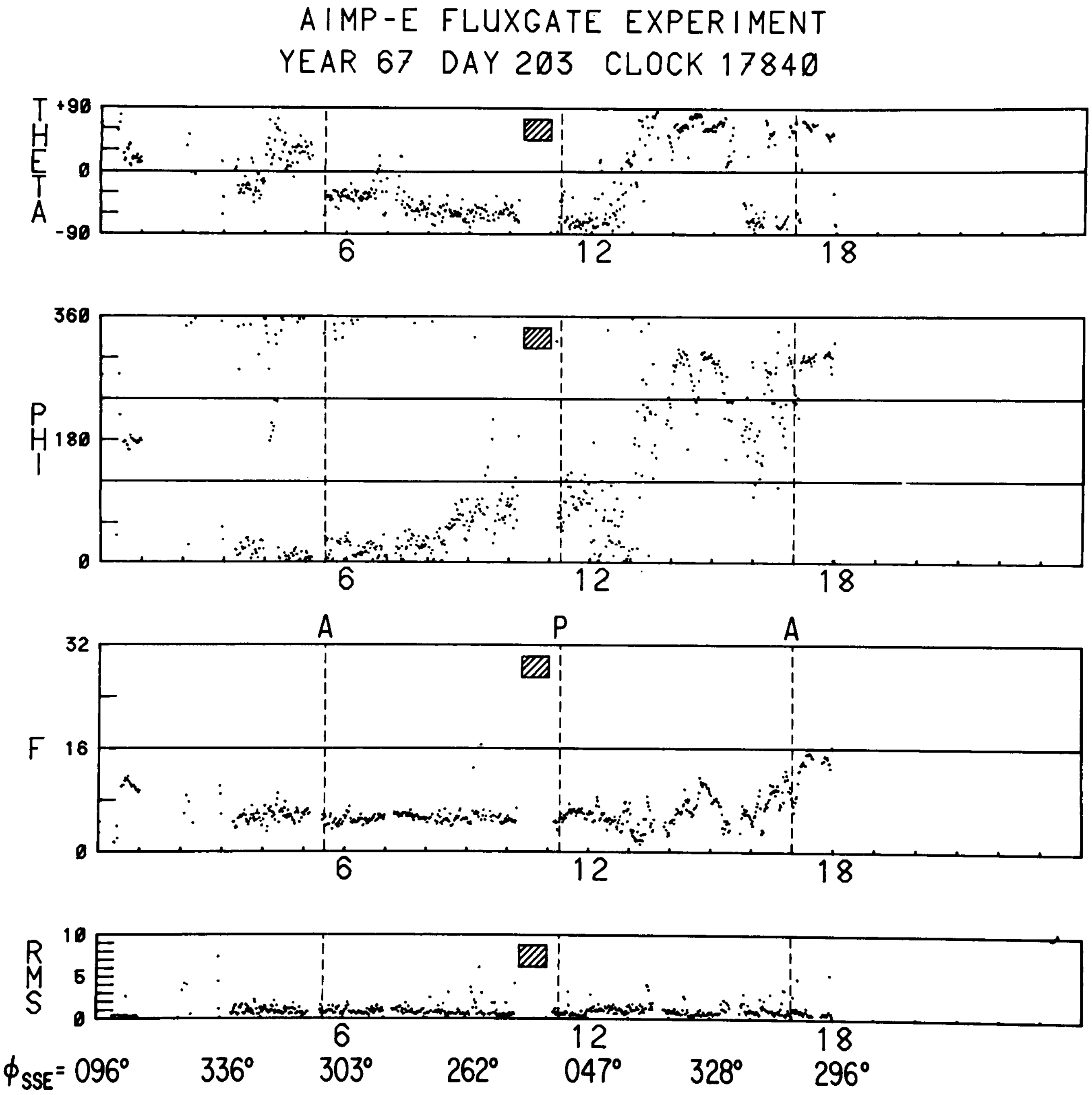

AIMP-E FLUXGATE EXPERIMENT
YEAR 67 DAY 203 CLOCK 17840
THETA
+90
0
-90
PHI
360
180
0
F
32
16
0
RMS
10
5
0
A
P
A
6
12
18
ϕ_{SSE}= 096°
336°
303°
262°
047°
328°
296°

FIGURE 6

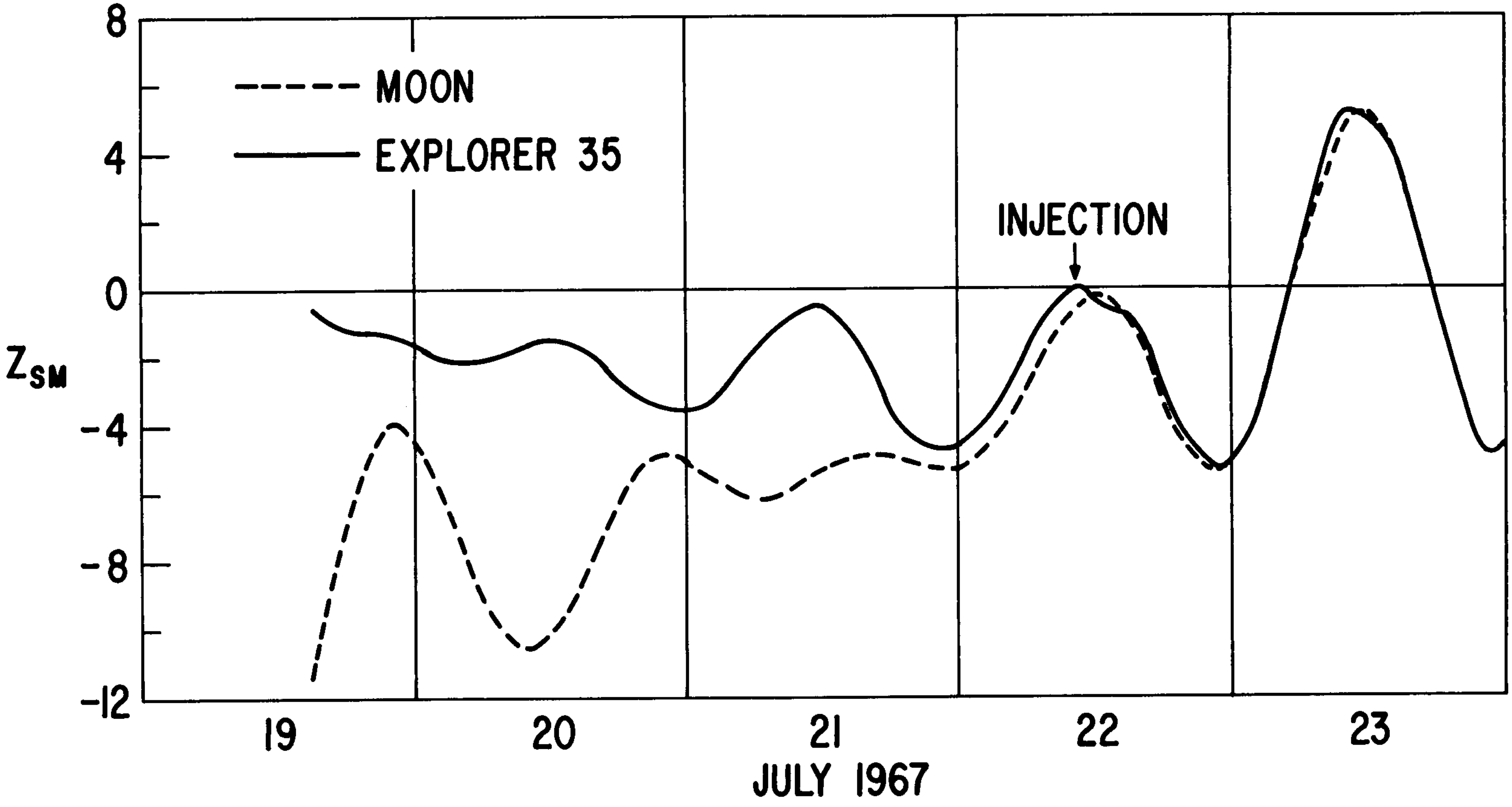

MOON
EXPLORER 35
INJECTION
8
4
0
-4
-8
-12
Z_SM
19
20
21
22
23
JULY 1967

FIGURE 7

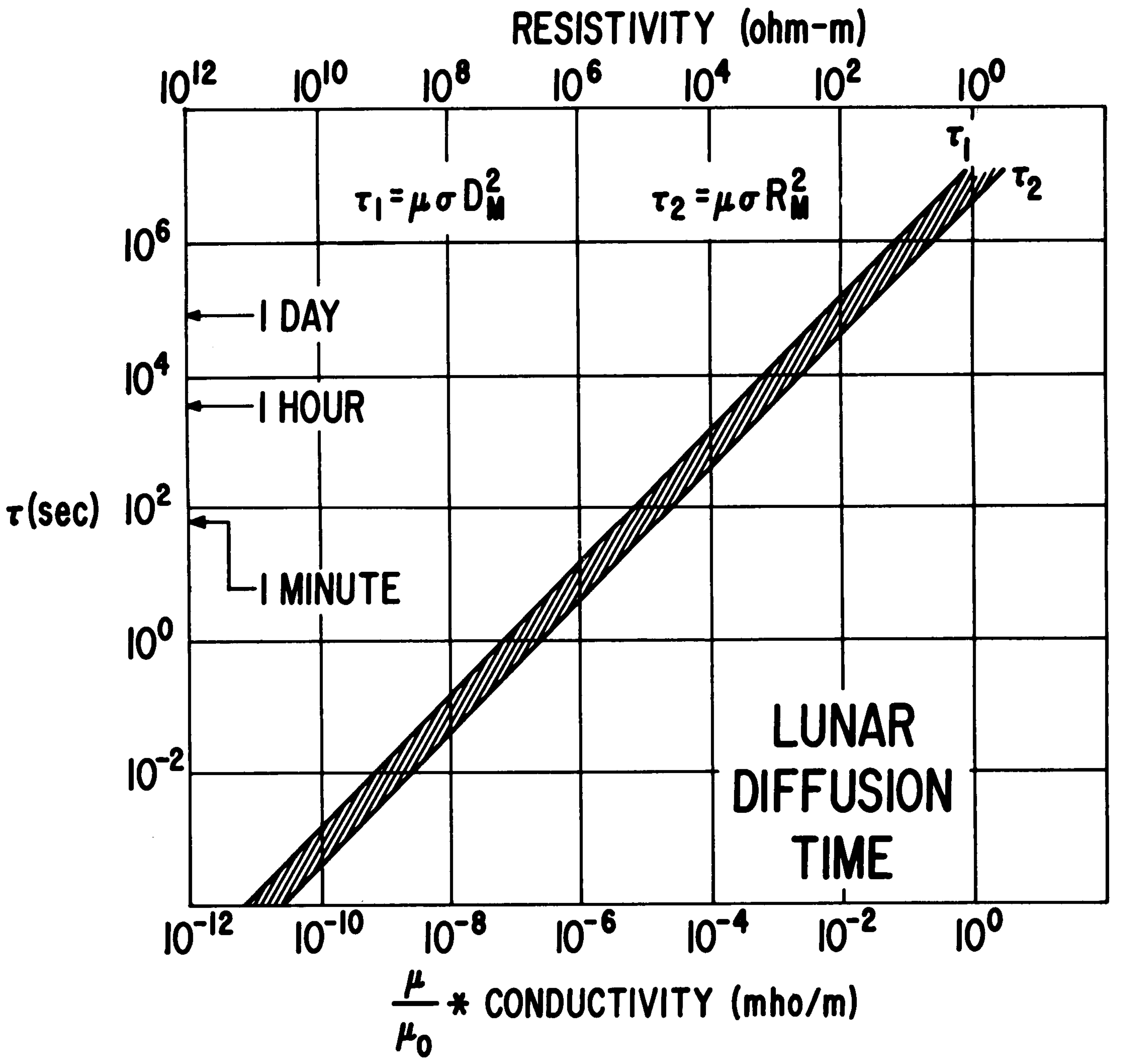

RESISTIVITY (ohm-m)
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
10^{0}
τ_1
τ_2
$\tau_1 = \mu \sigma D_M^2$
$\tau_2 = \mu \sigma R_M^2$
τ(sec)
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
1 DAY
1 HOUR
1 MINUTE
LUNAR DIFFUSION TIME
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
$\frac{\mu}{\mu_0}$ * CONDUCTIVITY (mho/m)

FIGURE 8