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VAN ALLEN BELT RADIATION ON TIROS/TOS/ITOS SPACECRAFTS

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

VAN ALLEN BELT RADIATION
ON TIROS/TOS/ITOS SPACECRAFTS

A special report prepared for the TIROS Project Office
with addendum on "Environment Models and Orbital Flux Calculations".

by

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September 1971

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Greenbelt, Maryland

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on TIROS/TOS/ITOS Spacecrafts

Foreword

In order to provide the project office, its manager, contractors, engineers, scientists, and experimenters with updated radiation data, old predictions of vehicle-encountered trapped-particle fluxes were re-evaluated and new calculations were performed. The final results, presented in tabular and graphical form, are analysed and discussed.

Additionally and in response to frequent inquiries about the models employed in the flux calculations, their proper use, the interpretation or accuracy of the obtained values and the correct application of the results, a special section was included in this report, preceding the introduction, that answers some of these querries, mainly in regards to validity, terminology, and usage.

Environment Models and Orbital Flux Calculations

From the time of its discovery in 1959 - 1960, the trapped radiation environment has consistently been described and modelled separately for electrons and for protons. Initially, this distinction was probably made out of necessity. At that time, the sheer magnitude and complexity of the modelling task favored this solution; that is, it became necessary to break the whole problem up into smaller manageable pieces and treat them independently.

Several years and many satellites later, as magnetospheric physics grew to a full fledged member of the scientific disciplines and a deeper understanding developed for the causality of the observed physical phenomena, it became apparent that the initial distinction was a fortuitous design of great merit. By then it had also become evident that the real high energy proton environment could most appropriately be approximated by static models (four initially, three now), while the electrons posed severe problems, displaying strong temporal variations throughout their entire trapping region, partially due to the vast deposition of artificial electrons from the STARFISH nuclear explosion in 1962, and partially due to solar cycle and magnetic storm effects.

Thus, it has long been customary to construct separate models for the two types of particles, a distinction which is now well accepted and established. Vette's "Models of the Trapped Radiation Environment" were designed along these lines. Today widely acclaimed, they have become standards and they are extensively used throughout the entire western world.

These models are periodically updated or revised to reflect changes or improvements in their data base. Up to this time they have always been static models but Dr. Vette and his group are presently working on a dynamic electron model which should be published soon. Currently the following models are in valid use: AE2 of 1964 (subsynchronous electrons), AE3 of 1967 (synchronous electrons), AP5 of 1967 (low energy protons), AP6 of 1964, AP1 of 1963, and AP7 of 1969 (high energy protons).

All models are by necessity approximations. The extent to which they predict correctly the real environment in intensity and energy distribution is given by an error- or uncertainty-factor, inseparably attached to each model. It is applied both as a multiplier and as divisor; if, for example, for a flux-value of 10^5 (particles per square centimeter per second) a factor 2 is given, then the upper and lower estimates for the intensity are 2×10^5 and 5×10^4.

Obviously, every calculation performed with any one of these models will inherently contain at least this uncertainty factor. Furthermore, it is evident that in electron calculations the final uncertainty factor may be significantly greater than the model factor, as long as a static model is being used. There can be no question or doubt as to the applicability of the uncertainty factor. Results obtained in any way or form from these models should be bracketed by an error bar determined by the uncertainty factor. This implies of course, that actual measurements are expected (to a high degree of probability) to fall within the given error bar.

It has been noted that at times confusion has arisen in the aerospace community as to the correct terminology to be employed when relating to radiation-belt data.

It is felt that this bewilderment would be significantly reduced if the term "model radiation environment" were selectively used only in connection with descriptions of the Van Allen Belts, such as Vette's AE2, AP6, etc. Such trapped particle models, in conjunction with dated magnetic field models and the orbit of a spacecraft, can then be utilized to determine the fluxes encountered by that satellite at a specified epoch.

Unfortunately it has happened that the term "model radiation environment" was occasionally used in reference to calculated flux predictions. Thus, special radiation data obtained exclusively from specific orbital flux integrations (i.e. total electron and proton intensities, characteristic of a unique trajectory), have been referred to as "A Model Radiation Envoronment" for a particular satellite. For instance, flux calculations made for the TIROS project were quoted by a contractor as " . . . a new NASA-1970 model radiation environment for the 790 n.mi.

TOS/ITOS orbit . . .," and older calculations were called " . . . the earlier 1965 model . . . ," again, in both instances, referring to results from orbital-flux integrations.

This is an unfortunate choice of nomenclature because it may convey the wrong impression about the nature of the data and it may lead to misunderstanding or confusion. In the context of orbital flux studies, "models of the environment" are only those constructed and published by Dr. Vette and his group at the National Space Science Data Center-GSFC (Formerly of Aerospace). Once issued they are standard, static and unchanging with regards not only to time but also with regards to application, at least until new ones appear. Subsequently, every single orbital flux calculation performed for any project office or for any mission requirement uses the same identical models, current at that time. To attach the term "model" to the end products of their use would imply that for the specific flightpath the results could in turn be used to again predict fluxes, when given different parameters or conditions, which of course is not the case.

But sometimes the misleading effect of this misnomer is further compounded when electrons and protons are summarily lumped together under the same deceptive heading. This last practice may be particularly confusing because it may produce several of the so-called "models" for a given satellite in a fixed year, if during that year more than two true environment models happened to be published. Assuming that whenever improved, real models do become available, the older ones are immediately replaced and new calculations are invariably performed, and since new proton and electron models are not published simultaneously, it may happen that revised data are issued to a project office several times during a particular year, some reflecting changes in the flux values of one type of particles only.

Furthermore, for a given trajectory, in addition to the electron and proton flux variations due to a routine model replacement, different electron fluxes may also be obtained from the same model by altering either the decay date or the decay process of the artificials, increasing even more the abundance of pseudo- "models"; a still further cause of variability of the computed electron intensities may be the inclusion of some modifying factor to account for long range solar cycle effects.

Finally, another source that may contribute to the proliferation of such "model radiation environments" is the periodic appearance of new geomagnetic field models or the recalculation of the expansion coefficients of an existing field model for a later date. In every instance, this would produce a variation in the vehicle encountered fluxes.

Now with regards to past TIROS data, all of the aforementioned causes did indeed affect, individually or jointly, the periodically released orbital-flux results, in a number of combinations. But in every case, the later results were preferable and superior to the older ones. This not only because each time they were obtained with improved calculational methods, from better field and environment models, but also because they utilized an expanded knowledge and understanding of the physical processes involved.

In view of these facts, it is advisable to discontinue the use of obsolete data as soon as possible, and caution should be exercised when comparing newer with older data because a superficial comparison of numbers would not serve a useful or practical purpose. It may in fact lead to the fallacious conclusion that the old values were "better", meaning in essence either "less severe" or "more convenient", while the "best" estimates in the sense of "closest to the real thing" (really needed for satellite design and operating criteria) are those later, updated fluxes.

The following part of this report presents and discusses the outcome of the latest orbital-flux study for the TIROS/ITOS/TOS spacecraft. Improved estimates resulted only for the electrons on account of new information about the decay of the artificials (Stassinopoulos and Verzariu, J.G.R., Vol. 75, No. 7, March 1, 1971), while the proton values remained unchanged.

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Introduction

High inclination circular and elliptical trajectories ($i > 55°$) or low inclination elliptical orbits of large eccentricity traverse the terrestrial radiation belts twice during each revolution. The vehicle thus executes a transverse motion in L-space, passing successively through a region of low L-values ($1.0 \leq L \leq 2.0$) and of high L-values ($2.0 \leq L \leq 6.6$), commonly referred to as the inner zone and the outer zone. The specified TIROS-TOS trajectories perform in a very similar way.

Although the inclination of the proposed TIROS orbits was fixed at 101 degrees prograde, which is identical to 79 degrees retrograde, the trajectories were nevertheless generated for a 79 degree prograde inclination. This was done in order to bypass difficulties usually encountered in the conversion of retrograde positions from geodetic polar to magnetic B-L coordinates (see: Stassinopoulos, DATA USERS' NOTE, NSSDC 67-27, Computer Programs for the Computation of B and L (May 1966), part III, p. 24), and only after previous test runs for both cases had established that the results will be about equal, if long enough intervals of flight-times are being considered and provided the orbit-periods are comparatively small ($t \simeq 2.5$ hrs.) and are not an exact divisor of 24 (hours in a day).

Obviously, this happens because the same limited area of space is being sampled by either prograde or retrograde trajectory and when the sampling density is sufficiently increased by extending the time in orbit (the flight duration considered in the calculations), then the statistical treatment of the data, the averaging process, produces the almost identical results.

Launch epoch for the TIROS mission is given as sometime in 1974, which approximately coincides with the next solar minimum. This means that conditions prevailing then in the radiation belts would most likely resemble those that existed during the last solar minimum, namely 1964, with the exception of the artificial "Starfish" electrons that populated the inner zone from July 1962 to about 1968. Since the electron fluxes are calculated with Vette's AE2 model , which describes the environment as it actually existed back in 1964, at which time the artificials were still vastly predominant in the inner zone, it is reasonable to assume that the outer zone predictions given in this report will be a good approximation for 1974. Of course, to obtain a reasonable approximation for the 1974 environment in the inner zone, the artificial component had to be removed; this was done by decaying the fluxes exponentially with experimentally determined decay lifetimes, defined as functions of B, L, and E (energy), up to an epoch, when it is felt, that natural background levels had been reached. Orbital flux integrations for high energy protons were performed with Vette's current models AP1, AP6, AP7 while low energy protons were obtained with King's AP5. All are static models, including the AE2, which do not consider temporal variations.. For the protons this is a valid represention because experimental measurements have shown that no significant changes with time have occurred. With the exception of the fringe areas of the proton belt, that is, at very low altitudes and at the outer edges of the trapping region, the possible error introduced by the static approximation lies well within the uncertainty factor of 2, attached to the models. Consequently, the proton models may be applied to any epoch without the need for an updating process.

Occasionally discontinuities appear in the proton spectra. These "breaks" occur because the complete proton environment is being described by three (formerly four) independent maps or grids, each valid only over a limited energy range; for certain critical orbital configurations the discontinuities are then produced when moving from one energy range to another. They are caused, in part, by the exponential energy parameter of the model which in many instances had to be extrapolated to make up for lacking data and, in part, to insufficient experimental measurements over some areas of B/L-space; furthermore, the discontinuities reflect the fact that the available data connot be completely matched at their overlap. In order to overcome such spectral breaks, a continuous weighted mean curve is usually drawn, connecting the adjacent segments; it should be regarded as an approximate spectral distribution. In doing this, the AP1 results ($30 < E(\mathrm{Mev}) < 50$) have to be totally ignored sometimes. The TIROS orbits belong to the affected group.

Classification of orbit integrated spectra as hard or soft is relative; it is based on an overall evaluation of near earth space in terms of circular trajectories between equatorial and polar orbits.

Attachment A contains other pertinent background information with regard to units, field models, trajectory generation and conversion, etc. At this point, we wish to emphasize again that our calculations are only approximations; we strongly recommend that all persons to receive parts of this report be advised about the uncertainty in our data.

Results: Analysis and Discussion

Our calculations for the two proposed TIROS orbits are summarised in Tables 1, 2 for electrons and Tables 3, 4 for protons. The superimposed spectral distributions of the two trajectories are given graphically for each type of particles in Figures 1 and 2 respectively, and a selected set of integral energies are plotted versus altitude in Figures 3 for electrons and 4 for protons.

As might be expected, Figures 1 and 2 indicate an increase in the average daily fluxes for higher altitudes, accompanied by a slight softening of the spectra, which for electrons above E = 1 Mev may be classified as "hard" for near earth space missions, while the protons rate a "hard" to "very hard" classification for energies E > 5 Mev. Figures 5 to 8 are computer plots depicting each characteristic electron and proton spectrum of the two flightpaths separately.

Table 5 indicates what percent of its total lifetime the satellite spends in "flux-free" regions of space, what percent of its total lifetime in "high intensity" regions, and while in the latter, what percent of its total daily flux it accumulates.

In the context of this study, the term "flux-free" applies to all regions of space where trapped-particle fluxes are less than one electron or proton per square centimeter per second, having energies

$E > .5$ Mev and $E > 5.$ Mev respectively; this includes regions outside the radiation belts. Similarly, we define as "high intensity" those regions of space, where the instantaneous, integral, omnidirectional, trapped-particle flux is greater than 10^5 electrons with energies $E > .5$ Mev, and greater than 10^3 protons with energies $E > 5.$ Mev. The values given in Table 5 are statistical averages, obtained over extended intervals of mission time. However, they may vary significantly from one orbit to the next, when individual orbits are considered.

Predictably, the high energy proton population, which occupies a smaller volume of the radiation belt, affords a larger flux-free time than the electrons. It should be noted that at the indicated heights, a change in altitude does not alter significantly the flux-free time afforded the satellite, in either the electron or the proton medium.

If the flux-free time is important in mission planning, it is advisable, before decisions are made, to evaluate and compare the radiation hazards or effects due to the predicted electron and proton fluxes, either in regard to the entire mission or in regard to specific mission functions or requirements. For, while the proton intensities are on the average about two orders of magnitude smaller than the electrons, and while they apparently do afford more flux-free time, their greater mass and harder spectra may prove more damaging to the mission than the more numerous electrons with their lesser flux-free time.

In Figure 9 the percentage of total lifetime T spent by the vehicle in the inner zone (T^i) and in the outer zone (T^o) is given, with the percent duration spent outside the trapped particle radiation belt ($L > 6.6$), denoted by T^e (T-external).

For any mission (j) then:

$$T_j = T_j^i + T_j^o + T_j^e = 100\%$$

Evidently, the high inclination TIROS/ITOS spends almost equal amounts of its entire lifetime in the inner and the outer zones, for both selected altitudes. It only briefly visits regions of space outside the Van Allen belts (about 15% of T_j). The satellite thus performs a complete sweep through magnetic L-space, which constitutes the transverse motion mentioned in the first paragraph, executed twice during each revolution (orbit). This information is used to evaluate the possible contribution of the outer zone solar cycle dependence to the uncertainty factor attached to the results.

The following related points are submitted for consideration in connection with the lifetime distribution over distinct regions of space:

a. Lasting solar cycle effects are more severely experienced in the <u>outer zone</u> (significant changes in the trapped electron population from solar minimum to solar maximum).

b. Energetic artificial electrons from high altitude nuclear explosions (Starfish) have displayed a remarkable longevity, <u>but only in the inner zone</u>; there they contaminated the environment for over 5 years, while they rapidly decayed to background levels in the outer zone (within weeks to months). A planned or accidental explosion of another atomic device with the appropriate yield and at the right latitude and altitude may, very likely, produce conditions similar to those experienced with "Starfish", transforming the inner zone again into a radiation hotbed.

c. Transient solar flare effects (high energy solar proton fluxes) may be especially hazardous and damaging <u>in regions external</u> to the trapped particle belts.

Figures 10 to 13 are additional computer plots for the two TIROS trajectories showing the vehicle encountered instantaneous peak electron ($E > .5$ Mev) and proton ($E > 5$ Mev) intensities per orbit for a sequence of about 25 revolutions. On all graphs a periodic pattern emerges that indicates a daily cycle of about 12 to 13 orbits which may shift slightly in the plotting. This is due to the relative orbit period, which determines the precession of the trajectory.

It is evident that altitude affects the peaks for both types of particles, but very little over the given range. The tendency is towards greater fluxes for higher altitudes. There is a relatively small variation in the peak-levels over a daily cycle (maximum about a factor of 5), contrary to other orbits, which experience flux-less intervals of time, occasionally lasting several revolutions.

Finally, for each of the two flight paths, two more computer plots are included, Figures 14 to 19, one for protons and one for electrons, depicting the characteristic averaged instantaneous intensities of the trajectory in terms of constant L-bands of .1 earth radius width; the percent of total lifetime spent in each L-interval is shown on the same graph by the contour marked with x's.

ATTACHMENT A

General Background Information

For the specified TIROS-TOS trajectories, orbit tapes were generated with an integration stepsize of one minute for a sufficiently long flighttime, so as to insure an adequate sampling of the ambient environment; on account of their periods, which determine the rate of orbit-precession, the following circular flight paths of 48-hour duration were produced:

Inclination	Altitude	Period
79° prograde (101° retrograde)	1463 km (790 n.m.)	1.919 hrs.
79° prograde (101° retrograde)	1667 km (900 n.m.)	1.995 hrs.

The orbits were subsequently converted from geocentric polar into magnetic B/L coordinates with McIlwain's INVAR program of 1965 and with the field routine ALLMAG by Stassinopoulos and Mead, utilizing the POGO (8/69) geomagnetic field model by Cain and Sweeney, calculated for the epoch 1974.0 (B is the field strength at a given point and L is the geocentric distance to the intersect of the field line, passing through that point, with the geomagnetic equator).

Orbital flux integrations were performed with Vette's current models of the environment, the AE2 for electrons and the AP1, AP6, AP7 for high energy protons. All are static models which do not consider temporal variations. See text and preceding it section for further details on this matter.

The results, relating to omnidirectional, vehicle encountered, integral, trapped particle fluxes, are presented in graphical and tabular form with the following unit convention:

1. Daily averages: total trajectory integrated flux averaged into particles/cm^2 day,
2. Totals per orbit: non-averaged, single-orbit integrated flux in particles/cm^2 orbit,
3. Peaks per orbit: highest orbit-encountered instantaneous flux in particles/cm^2 sec,

where 1 orbit = 1 revolution.

Please note: we wish to emphasize the fact that the data presented in this report are only approximations. We do not believe the results to be any better than a factor of 2 for the protons and a factor of 3 for the electrons. It is advisable to inform all potential users about this uncertainty in the data.

TABLE 4

ORBITAL FLUX STUDY WITH COMPOSITE ELECTRON ENVIRONMENT* (VETTES AE2) * DATE OF RUN = YEAR 1971. DAY 0182
FLUXES EXPONENTIALLY DECAYED WITH DECAY-FACTOR DI = VETTE TBLE *** DECAY DATE = YEAR 1967. . MONTH 6. . DAY 0.

AVERAGED FLUXES ON THIS TABLE ARE IN UNITS OF PARTICLES/CM**2/DAY *** NON-AVERAGED FLUXES ARE IN UNITS OF PARTICLES/CM**2/SEC
ALL FLUXES ON THIS TABLE ARE FOR ENERGIES E>.5MEV (EXCEPT WHERE ENERGY IS SPECIFIED. AS IN SPECTRUM)

INCLINAT.= 79 * PERIG.= 1463 * APOG.= 1463 KM * B&L ORBIT TAPE TO 8228 * PERIOD = .919 * VEHICLE = TIROS-TOS

SPECTRUM IN % DE

ENERGY RANGES (MEV)	AVERAGED TOTAL FLUX (PER DAY)	SPECTRUM (PER CENT)
0-.5	1.197E 11	70.88
.5-1	2.464E 10	14.59
1-2	1.677E 10	9.93
2-3	5.172E 09	3.06
3-4	1.698E 09	1.01
4-5	5.862E 08	0.35
5-6	2.096E 08	0.12
6-7	7.512E 07	0.04
GT.7	4.146E 07	0.02
TOTAL =	1.689E 11	100.00

COMPOSITE ORBIT SPECTRUM

ENERGY GRTR.THAN (MEV)	AVERAGED INTEG.FLUX (PER DAY)
0.0	1.689E 11
0.25	7.884E 10
0.50	4.919E 10
0.75	3.405E 10
1.00	2.455E 10
1.25	1.817E 10
1.50	1.363E 10
1.75	1.028E 10
2.00	7.782E 09
2.25	5.839E 09
2.50	4.432E 09
2.75	3.374E 09
3.00	2.610E 09
3.25	2.001E 09
3.50	1.540E 09
3.75	1.187E 09
4.00	9.119E 08
4.25	7.094E 08
4.50	5.544E 08
4.75	4.136E 08
5.00	3.256E 08
5.25	2.511E 08
5.50	1.944E 08
5.75	1.497E 08
6.00	1.166E 08
6.25	8.976E 07
6.50	6.981E 07
6.75	5.251E 07
7.00	4.146E 07

EXPOSURE INDEX

INTENSITY RANGES (EL/CM**2/SEC)	DURATION OF EXPOSURE (HRS)	TOTAL NO. OF ACCUMULATED PARTICLES (E>.5)
ZERO FLUX	11.4	4.721E 01
1.E0-1.E2	0.483	1.063E 05
1.E2-1.E3	3.60	6.101E 06
1.E3-1.E4	7.02	1.037E 08
1.E4-1.E5	8.25	1.253E 09
1.E5-1.E6	11.2	1.516E 10
1.E6-1.E7	5.88	7.326E 10
1.E7-1.E8	0.233	8.597E 09
1.E8-INFIN	0.0	0.0
TOTAL =	48.017	9.838E 10

TABLE 2

ORBITAL FLUX STUDY WITH COMPOSITE ELECTRON ENVIRONMENT* (VETTES AE2) * DATE OF RUN = YEAR 1971, DAY 0182
FLUXES EXPONENTIALLY DECAYED WITH DECAY-FACTOR D1 = VETTE TBLE *** DECAY DATE = YEAR 1967. , MONTH 6. , DAY 0.

AVERAGED FLUXES ON THIS TABLE ARE IN UNITS OF PARTICLES/CM**2/DAY *** NON-AVERAGED FLUXES ARE IN UNITS OF PARTICLES/CM**2/SEC
ALL FLUXES ON THIS TABLE ARE FOR ENERGIES E>.5MEV (EXCEPT WHERE ENERGY IS SPECIFIED, AS IN SPECTRUM)

INCLINAT.= 79 * PERIG.= 1607 * APOG.= 1667 KM * B&L ORBIT TAPE TC 8229 * PERIOD = 1.555 * VEHICLE = TIROS-TOS

SPECTRUM IN % DE

ENERGY RANGES (MEV)	AVERAGED TOTAL FLUX (PER DAY)	SPECTRUM (PER CENT)
0-.5	1.584E 11	71.53
.5-1	3.992E 10	14.40
1-2	2.647E 10	9.55
2-3	8.323E 09	3.00
3-4	2.757E 09	0.99
4-5	9.476E 08	0.34
5-6	3.357E 08	0.12
6-7	1.155E 08	0.04
GT.7	6.526E 07	0.02
TOTAL =	2.773E 11	100.00

COMPOSITE ORBIT SPECTRUM

ENERGY GR.THAN (MEV)	AVERAGED INTEG.FLUX (PER DAY)
0.0	2.773E 11
0.25	1.276E 11
0.50	7.894E 10
0.75	5.433E 10
1.00	3.902E 10
1.25	2.893E 10
1.50	2.172E 10
1.75	1.652E 10
2.00	1.255E 10
2.25	9.433E 09
2.50	7.174E 09
2.75	5.471E 09
3.00	4.225E 09
3.25	3.239E 09
3.50	2.482E 09
3.75	1.912E 09
4.00	1.468E 09
4.25	1.137E 09
4.50	8.381E 08
4.75	6.661E 08
5.00	5.204E 08
5.25	4.007E 08
5.50	3.096E 08
5.75	2.374E 08
6.00	1.847E 08
6.25	1.429E 08
6.50	1.103E 08
6.75	8.294E 07
7.00	6.526E 07

EXPOSURE INDEX

INTENSITY RANGES (EL/CM**2/SEC)	DURATION OF EXPOSURE (HRS)	TOTAL NO. OF ACCUMULATED PARTICLES (E>.5)
ZERO FLUX	11.6	0.0
1.E0-1.E2	0.0	0.0
1.E2-1.E3	2.62	4.505E 06
1.E3-1.E4	4.90	7.501E 07
1.E4-1.E5	7.07	1.103E 09
1.E5-1.E6	12.9	1.730E 10
1.E6-1.E7	8.12	1.067E 11
1.E7-1.E8	0.817	3.267E 10
1.E8-INFIN	0.0	0.0
TOTAL =	48.017	1.575E 11

TABLE 3

AVERAGED FLUXES ON THIS TABLE ARE IN UNITS OF PARTICLES/CM**2/DAY *** NON-AVERAGED FLUXES ARE IN UNITS OF PARTICLES/CM**2/SEC
ALL FLUXES ON THIS TABLE ARE FOR ENERGIES E>5 MEV (EXCEPT WHERE ENERGY IS SPECIFIED, AS IN SPECTRUM)

ORBITAL FLUX STUDY FOR COMPOSITE PROTON ENVIRONMENT * GRIDS AP1,AP7,AP6,AP5 * DATE OF RUN = YEAR 1971, DAY 9182
INCLINAT.= 79 * PERIG.= 1463 * APOG.= 1463 KM * B&L ORBIT TAPE TO 8220 * PERIOD = 1.919 * VEHICLE =.TIROS-TOS

HIGH ENERGY

SPECTRUM IN % DE

ENERGY RANGES (MEV)	AVERAGED TOTAL FLUX (PER DAY)	SPECTRUM (PER CENT)
3-5	6.384E 08	49.446
5-15	4.608E 08	35.693
15-30	9.398E 07	7.2[illegible]0
30-50	2.563E 07	1.996
50-100	2.645E 07	2.049
>100	4.579E 07	3.547
TOTAL =	1.291E 09	100.00

COMPOSITE ORBIT SPECTRUM

ENERGY GRTR.THAN (MEV)	AVERAGED INTEG.FLUX (PER DAY)
1	NOT VALID
3	1.291E 09
5	6.527E 08
7	4.361E 08
9	3.286E 08
11	2.646E 08
13	2.221E 08
15	1.919E 08
18	1.599E 08
21	1.375E 08
24	1.209E 08
27	1.081E 08
30	9.787E 07
35	7.641E 07
40	6.109E 07
45	4.929E 07
50	7.224E 07
60	6.586E 07
70	6.009E 07
80	5.486E 07
90	5.011E 07
100	4.579E 07

EXPOSURE INDEX

INTENSITY RANGES (PT/CM**2/SEC)	DURATION OF EXPOSURE (HRS)	TOTAL NO. OF ACCUMULATED PARTICLES (E>5)
0.E0-1.E0	19.633	1.171E 04
1.E0-1.E1	2.300	3.214E 04
1.E1-1.E2	2.167	3.182E 05
1.E2-1.E3	4.917	7.710E 06
1.E3-1.E4	10.767	1.685E 08
1.E4-1.E5	8.233	1.129E 09
1.E5-OVER	0.0	0.0
TOTAL =	48.000	1.306E 09

TABLE 8

AVERAGED FLUXES ON THIS TABLE ARE IN UNITS OF PARTICLES/CM**2/DAY *** NON-AVERAGED FLUXES ARE IN UNITS OF PARTICLES/CM**2/SEC
ALL FLUXES ON THIS TABLE ARE FOR ENERGIES E>5 MEV (EXCEPT WHERE ENERGY IS SPECIFIED, AS IN SPECTRUM)

ORBITAL FLUX STUDY FOR COMPOSITE PROTON ENVIRONMENT * [illegible] P1,AP7,AP6,AP5 * DATE OF RUN = YEAR 1971, DAY 0167
INCLINAT.= 79 * PERIG.= 1667 * APOG.= 1667 KM * [illegible] ORBIT TAPE TO 0220 * PERIOD = 1.995 * VEHICLE =.TIROS-TOS

HIGH ENERGY

SPECTRUM IN % OE

ENERGY RANGES (MEV)	AVERAGED TOTAL FLUX (PER DAY)	SPECTRUM (PER CENT)
3-5	1.164E 09	50.873
5-15	8.203E 08	35.848
15-30	1.575E 08	6.885
30-50	4.644E 07	2.030
50-100	3.709E 07	1.621
>100	6.280E 07	2.744
TOTAL =	2.288E 09	100.00

COMPOSITE ORBIT SPECTRUM

ENERGY GRTR.THAN (MEV)	AVERAGED INTEG.FLUX (PER DAY)
1	NOT VALID
3	2.288E 09
5	1.124E 09
7	7.330E 08
9	5.423E 08
11	4.290E 08
13	3.559E 08
15	3.039E 08
18	2.494E 08
21	2.117E 08
24	1.841E 08
27	1.630E 08
30	1.463E 08
35	1.151E 08
40	9.009E 07
45	7.113E 07
50	9.909E 07
60	9.095E 07
70	8.286E 07
80	7.552E 07
90	6.885E 07
100	6.280E 07

EXPOSURE INDEX

INTENSITY RANGE! (PT/CM**2/SEC)	DURATION OF EXPOSURE (HRS)	TOTAL NO. OF ACCUMULATED PARTICLES (E>5)
0.E0-1.E0	18.000	9.692E 03
1.E0-1.E1	2.217	2.520E 04
1.E1-1.E2	8.833	1.132E 05
1.E2-1.E3	2.100	4.520E 06
1.E3-1.E4	10.883	1.759E 08
1.E4-1.E5	12.083	1.606E 09
1.E5-OVER	1.100	4.620E 08
TOTAL =	48.000	2.249E 09

Table 5

TIROS/TOS

Circular

Inclination 79°

Trajectory #1 : 1463 km Alt.

Trajectory #2 : 1667 km Alt.

Decay Date: 1967.6

	Electrons (E≥.5 Mev)		Protons (E>5. Mev)	
	Traj. #1	Traj. #2	Traj. #1	Traj. #2
1. Fraction of total lifetime spent in flux-free regions* of space:	23.75%	24.17%	40.90%	39.17%
2. Fraction of total lifetime spent in high-intensity regions* of Van Allen Belts:	36.07%	45.49%	39.58%	50.14%
3. Fraction of total daily flux accumulated during (2):	98.61%	99.22%	99.43%	99.78%

*See text for definition

Figure 1

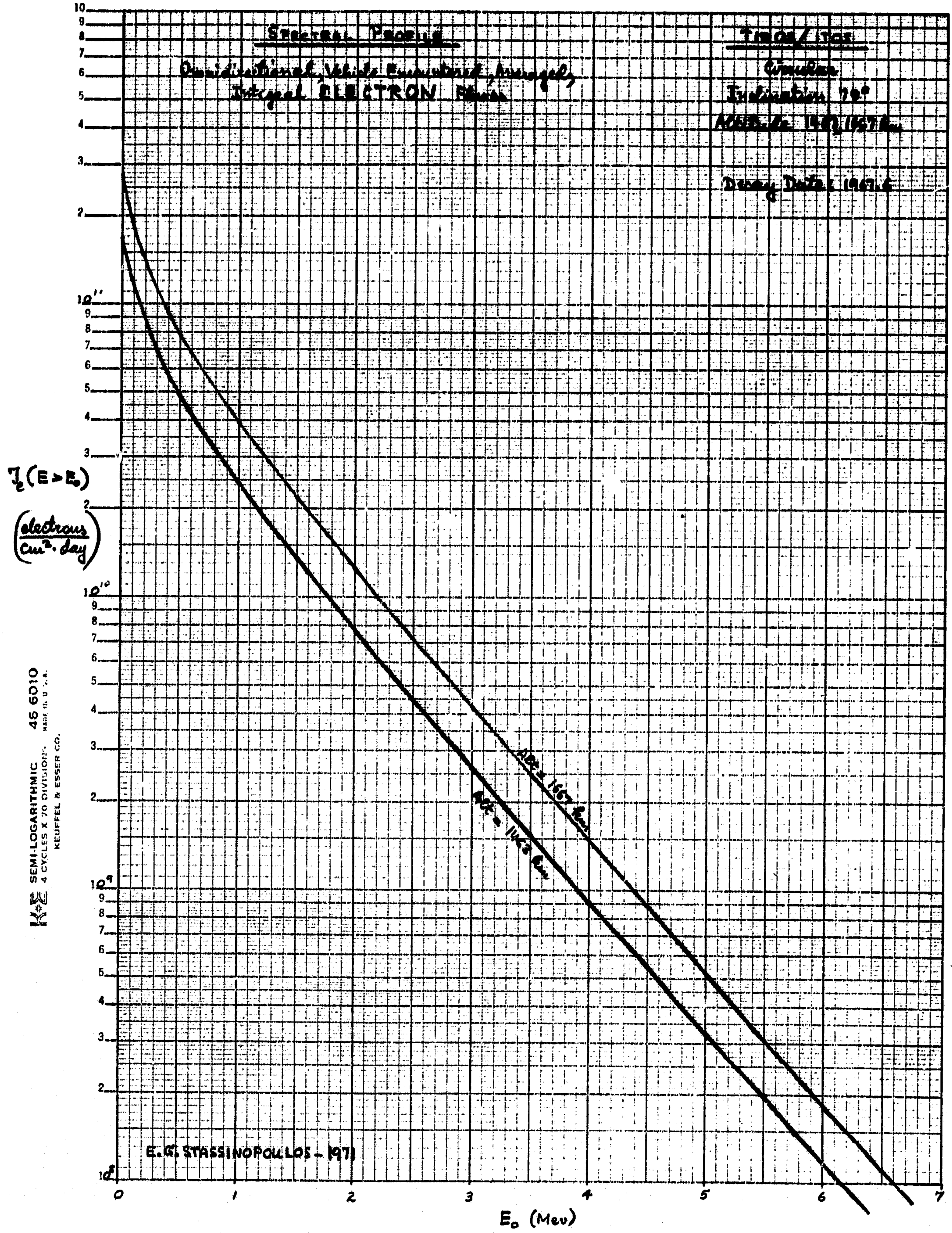

SPECTRAL PROFILE
Omnidirectional, Vehicle Encountered, Averaged
Integral ELECTRON Fluxes
TIROS/ITOS
Circular
Inclination 79°
Decay Date: 1967.6
$J_e(E > E_o)$
(electrons / cm^2 · day)
E_o (Mev)
Alt = 1667 km
Alt = 1463 km
E. G. STASSINOPOULOS - 1971

Figure 2

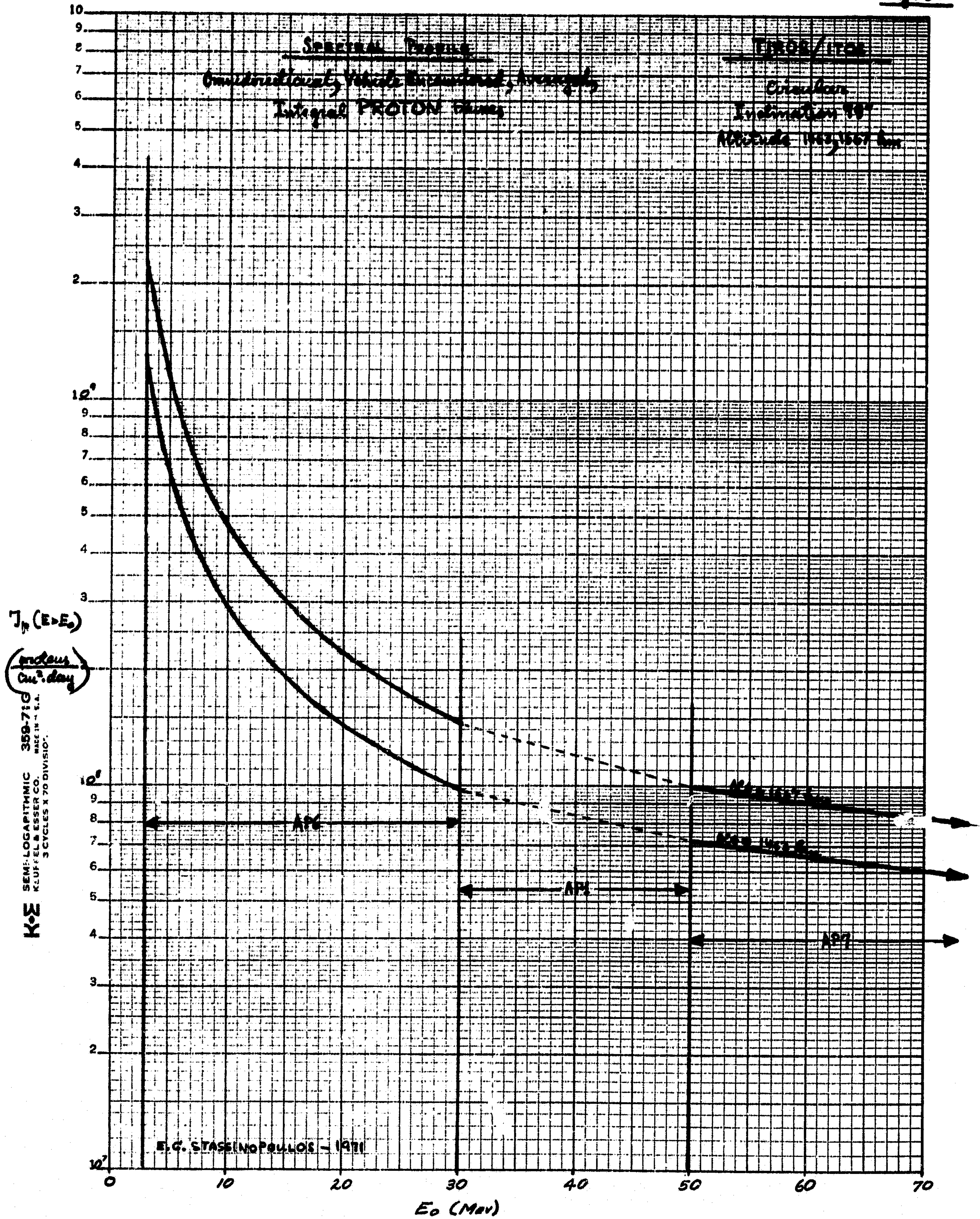
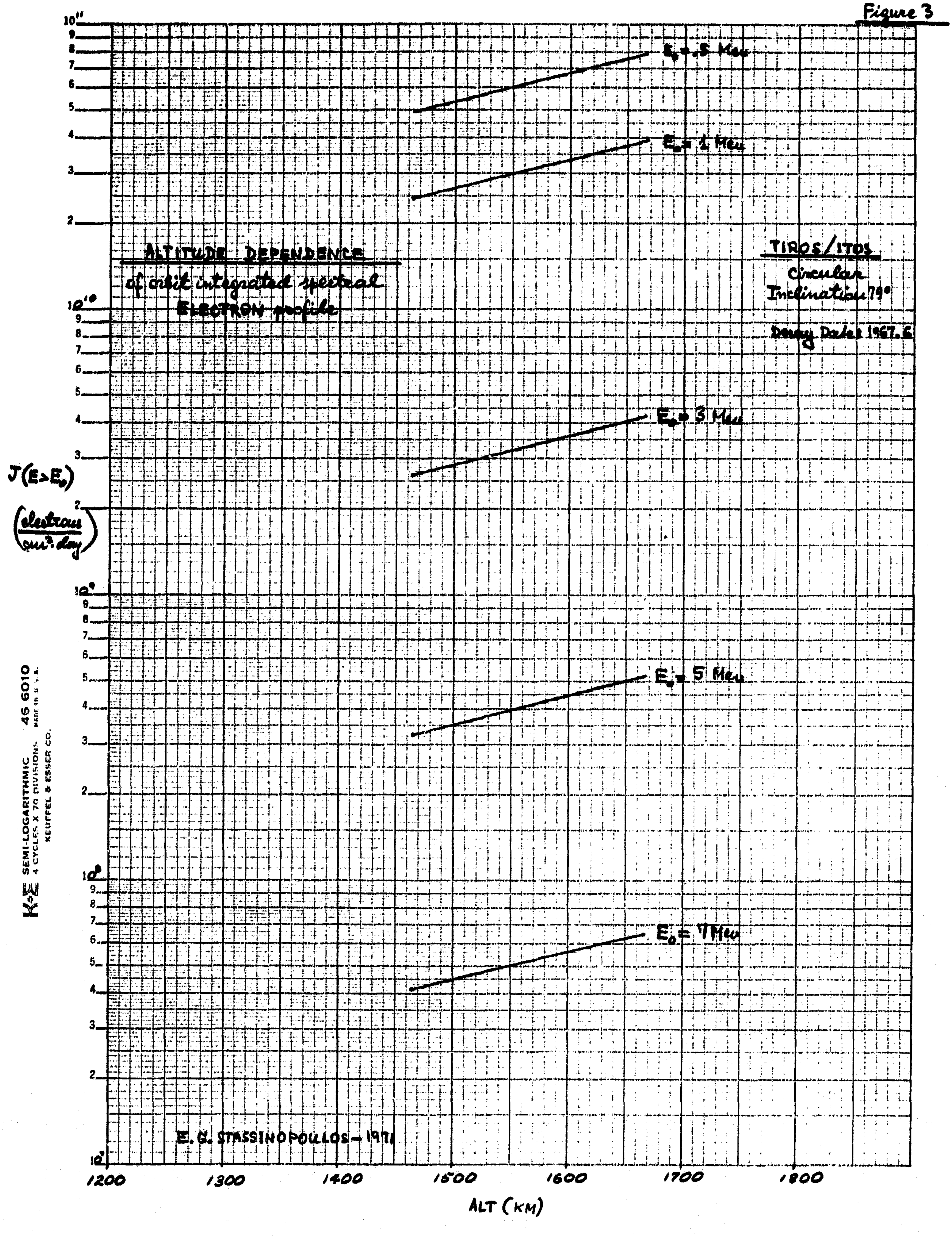
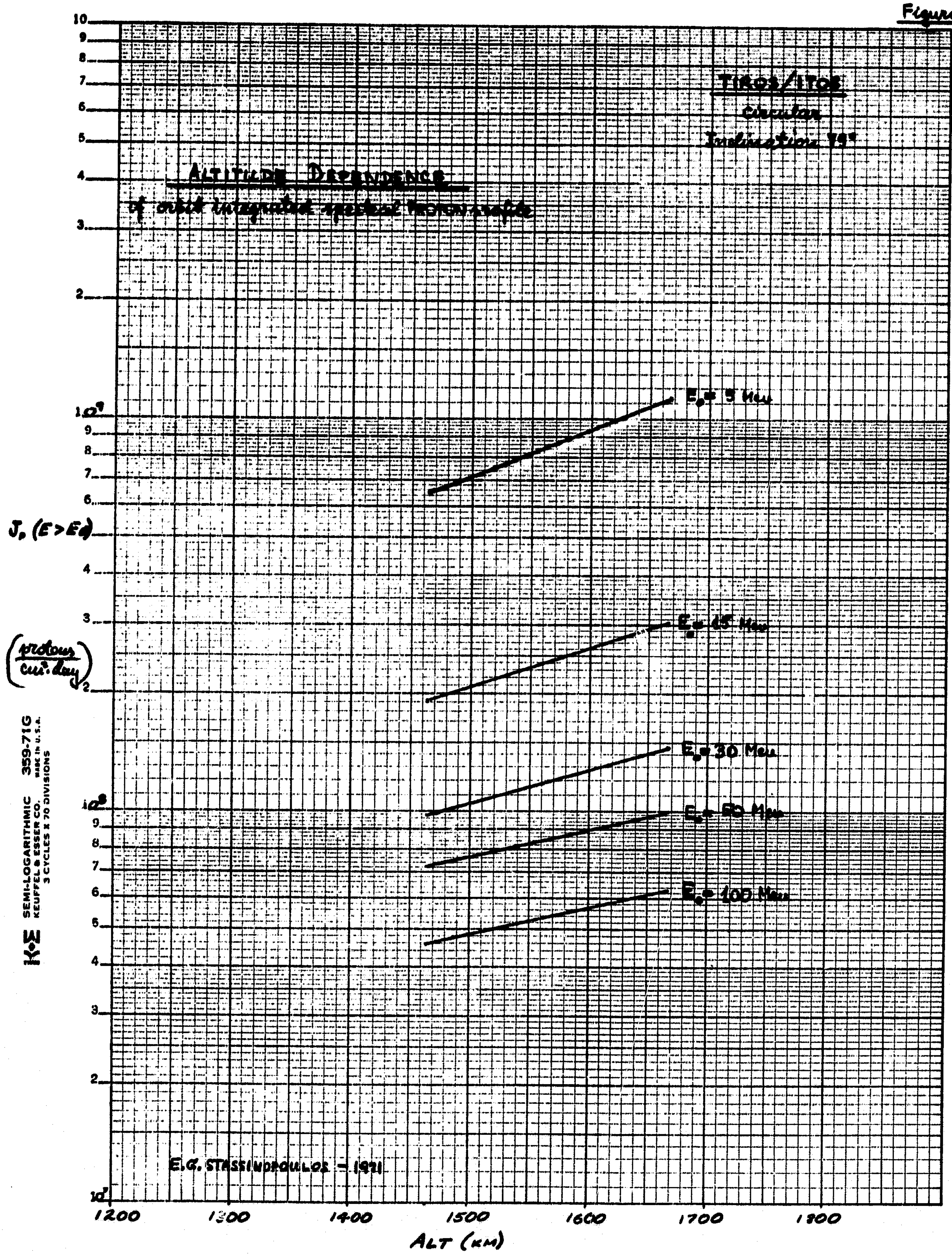

SPECTRAL PROFILE
Omnidirectional, Vehicle Encountered, Averaged,
Integral PROTON Fluxes
TIROS/ITOS
Circular
Inclination 98°
Altitude 1463, 1567 km
AP6
AP8
AP7
E.G. STASSINOPOULOS – 1971
$J_p\,(E>E_o)$
(protons / cm².day)
E_o (Mev)
0
10
20
30
40
50
60
70
10
9
8
7
6
5
4
3
2
10^8
10^7
K+E SEMI-LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

Figure 3

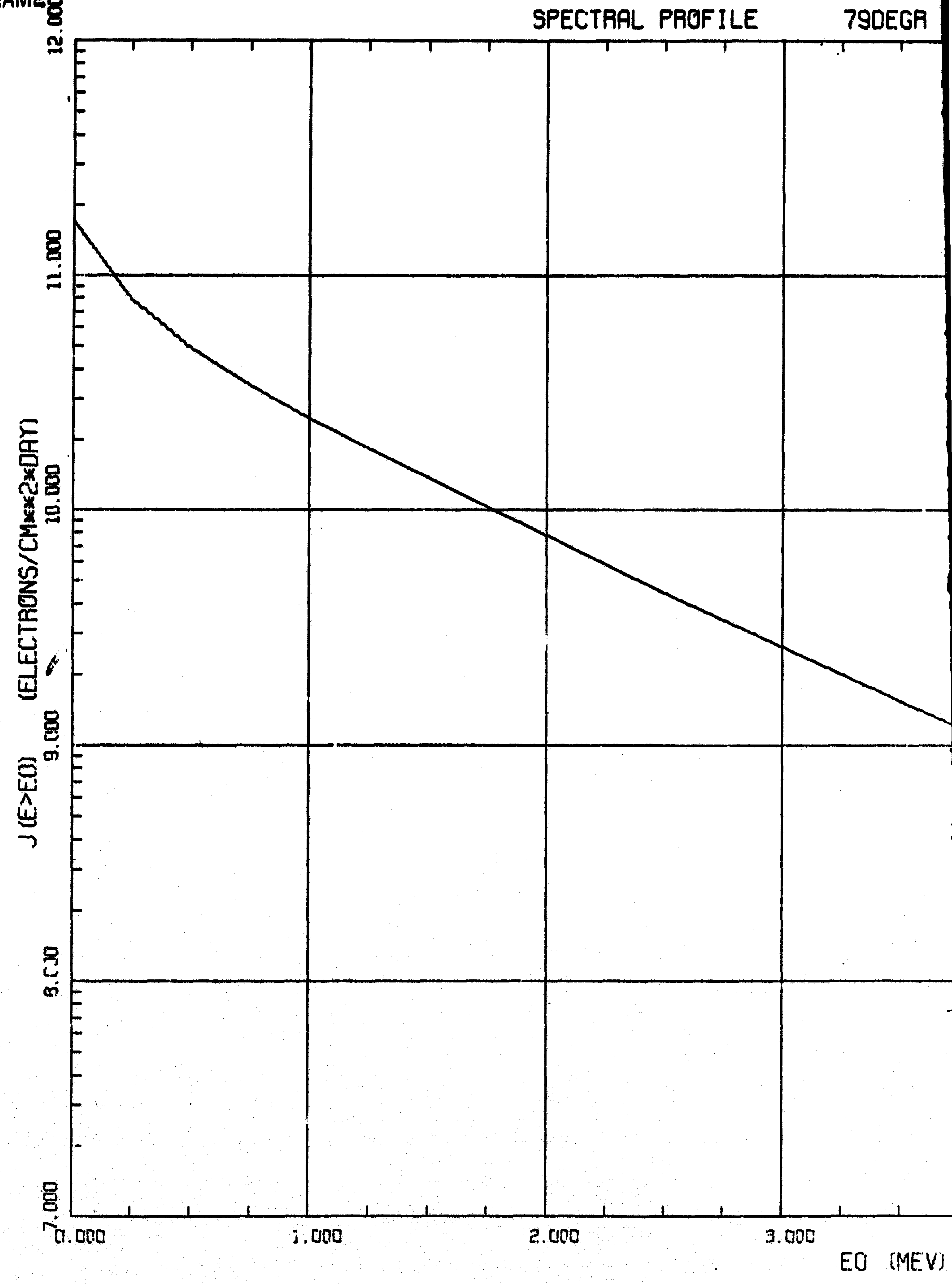


ALTITUDE DEPENDENCE
of orbit integrated spectral
ELECTRON profile
TIROS/ITOS
Circular
Inclination 79°
Decay Date: 1967.6
$E_0 = .5$ Mev
$E_0 = 1$ Mev
$E_0 = 3$ Mev
$E_0 = 5$ Mev
$E_0 = 7$ Mev
$J(E>E_0)$
(electrons / cm². day)
ALT (KM)
1200
1300
1400
1500
1600
1700
1800
E. G. STASSINOPOULOS – 1971
SEMI-LOGARITHMIC 46 6010
4 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

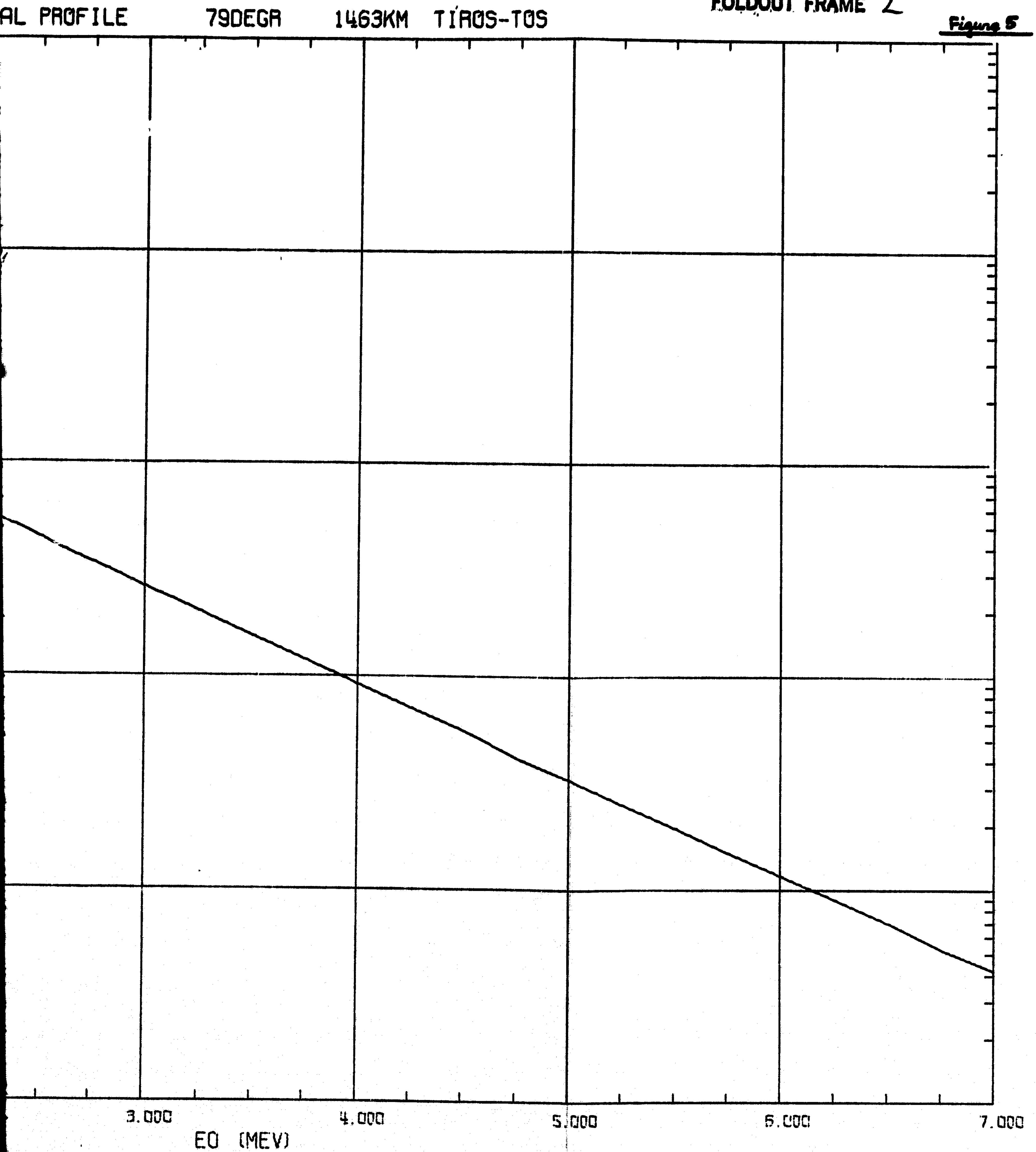
Figure


TIROS/ITOS
Circular
Inclination 79°
ALTITUDE DEPENDENCE
of orbit integrated spectral proton fluxes
$E_0 = 5$ Mev
$E_0 = 15$ Mev
$E_0 = 30$ Mev
$E_0 = 50$ Mev
$E_0 = 100$ Mev
$J_p (E > E_0)$
(protons / cm². day)
E.G. STASSINOPOULOS – 1971
ALT (KM)
1200
1300
1400
1500
1600
1700
1800
10^9
10^8
10^7
SEMI-LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

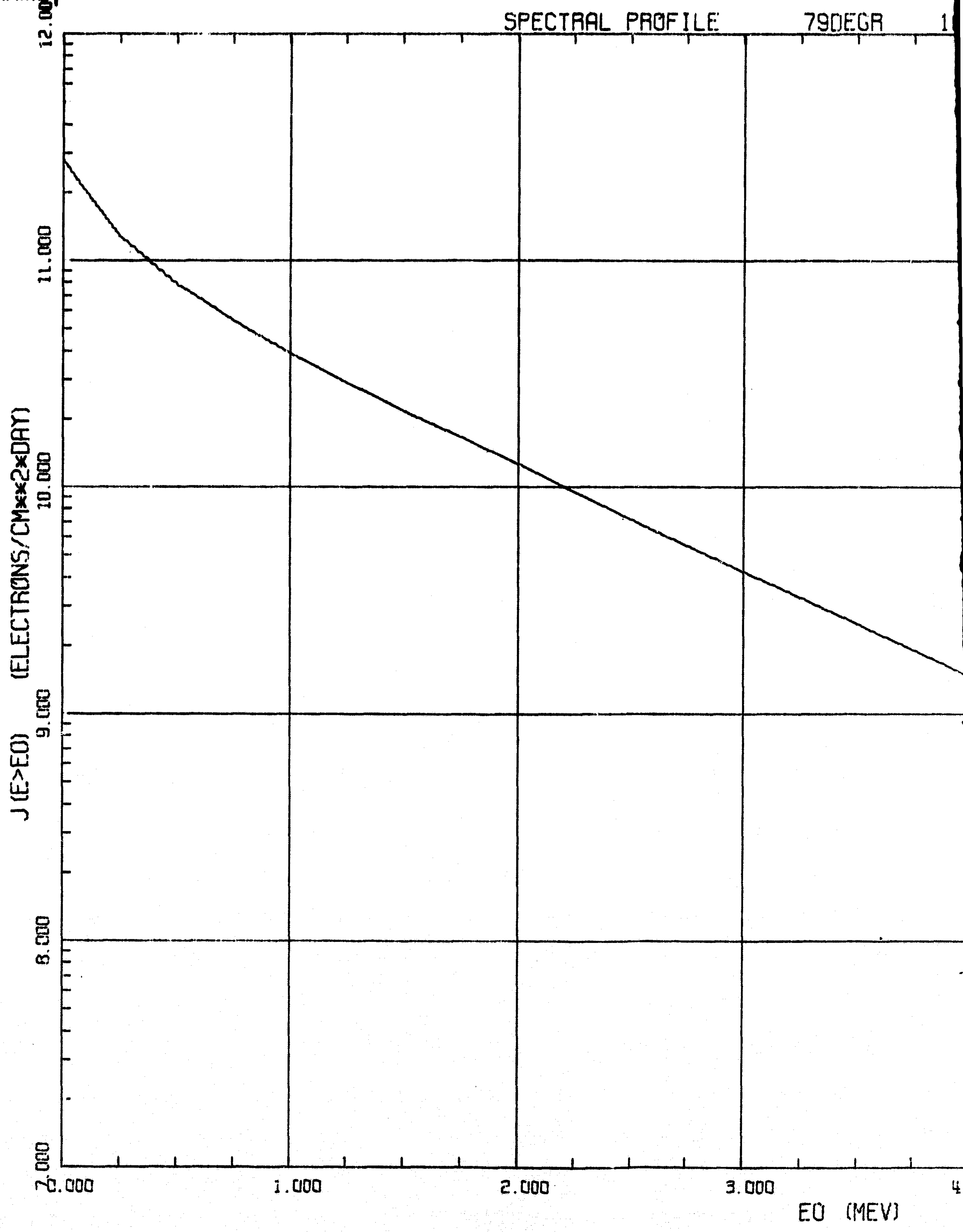
FOLDOUT FRAME 1



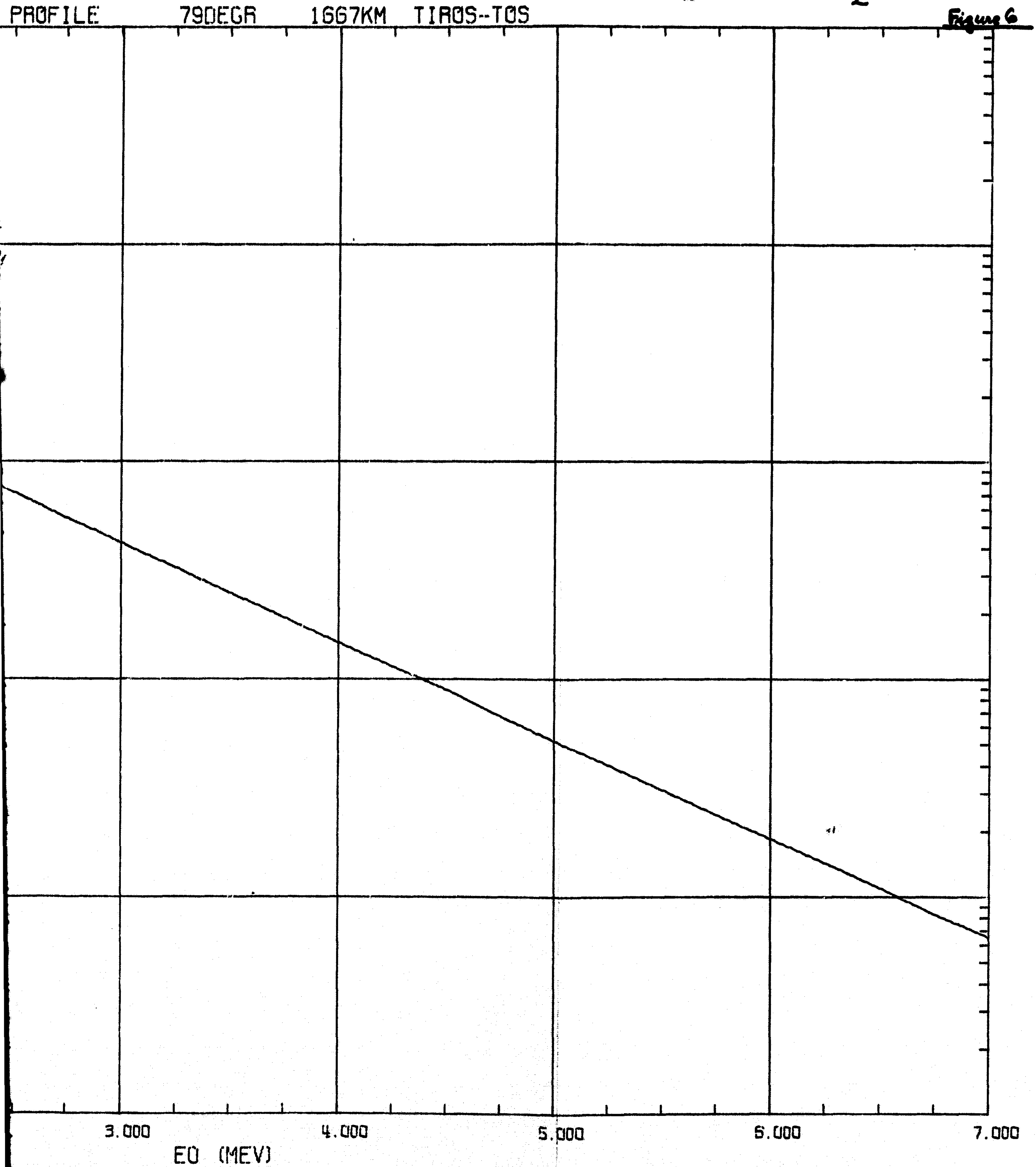
FOLDOUT FRAME 2



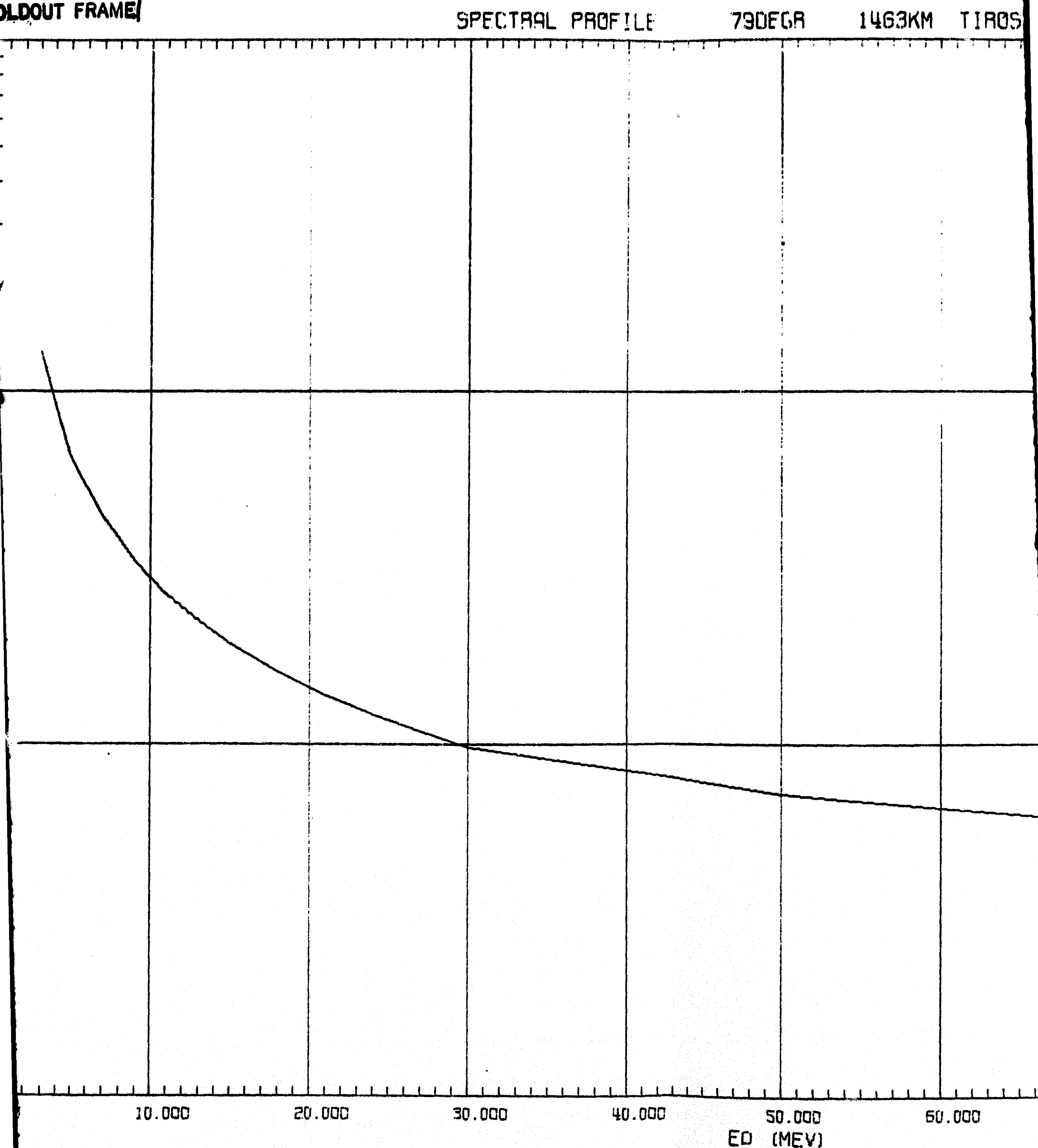
FOLDOUT FRAME 1



FOLDOUT FRAME 2



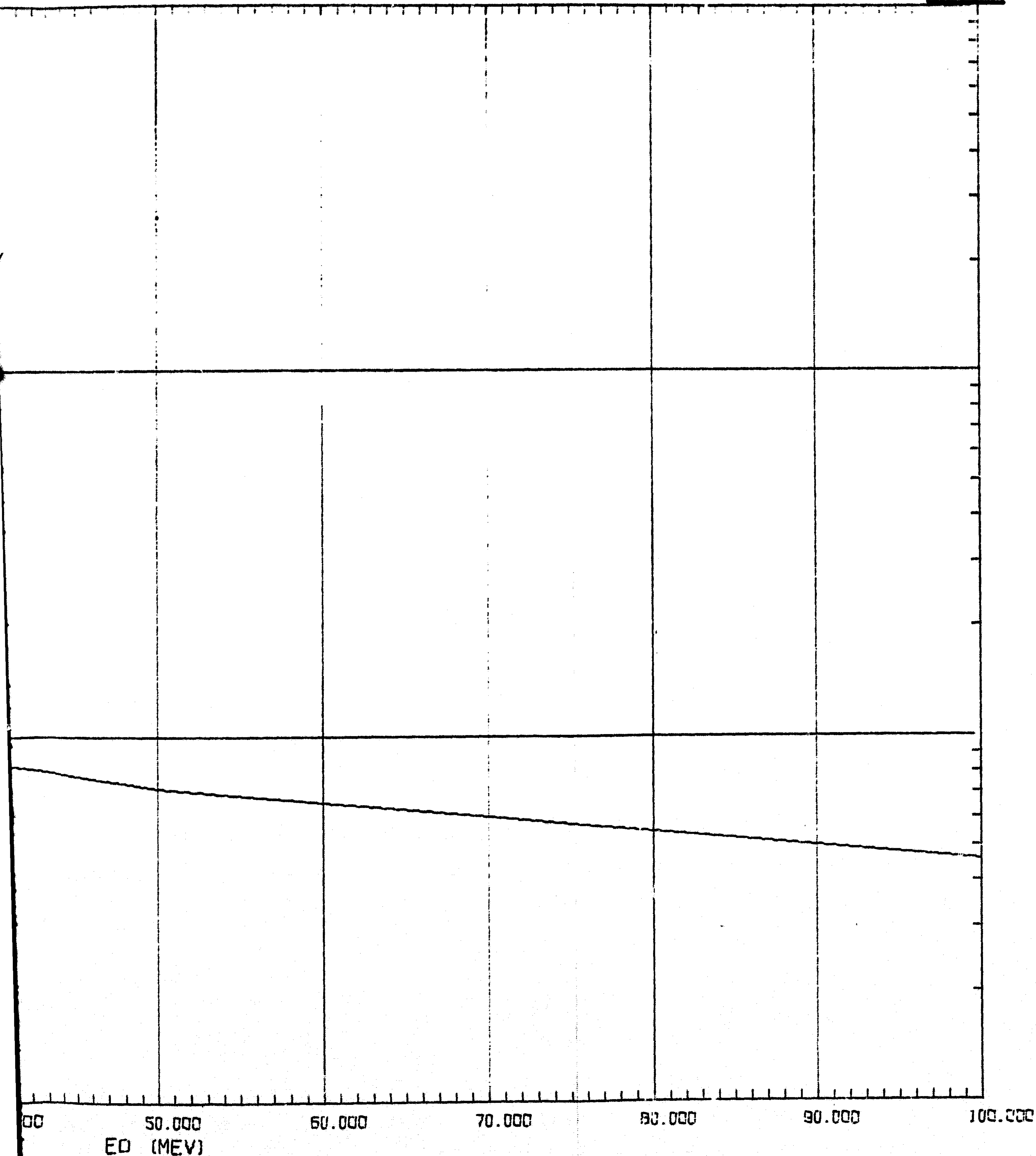
FOLDOUT FRAME



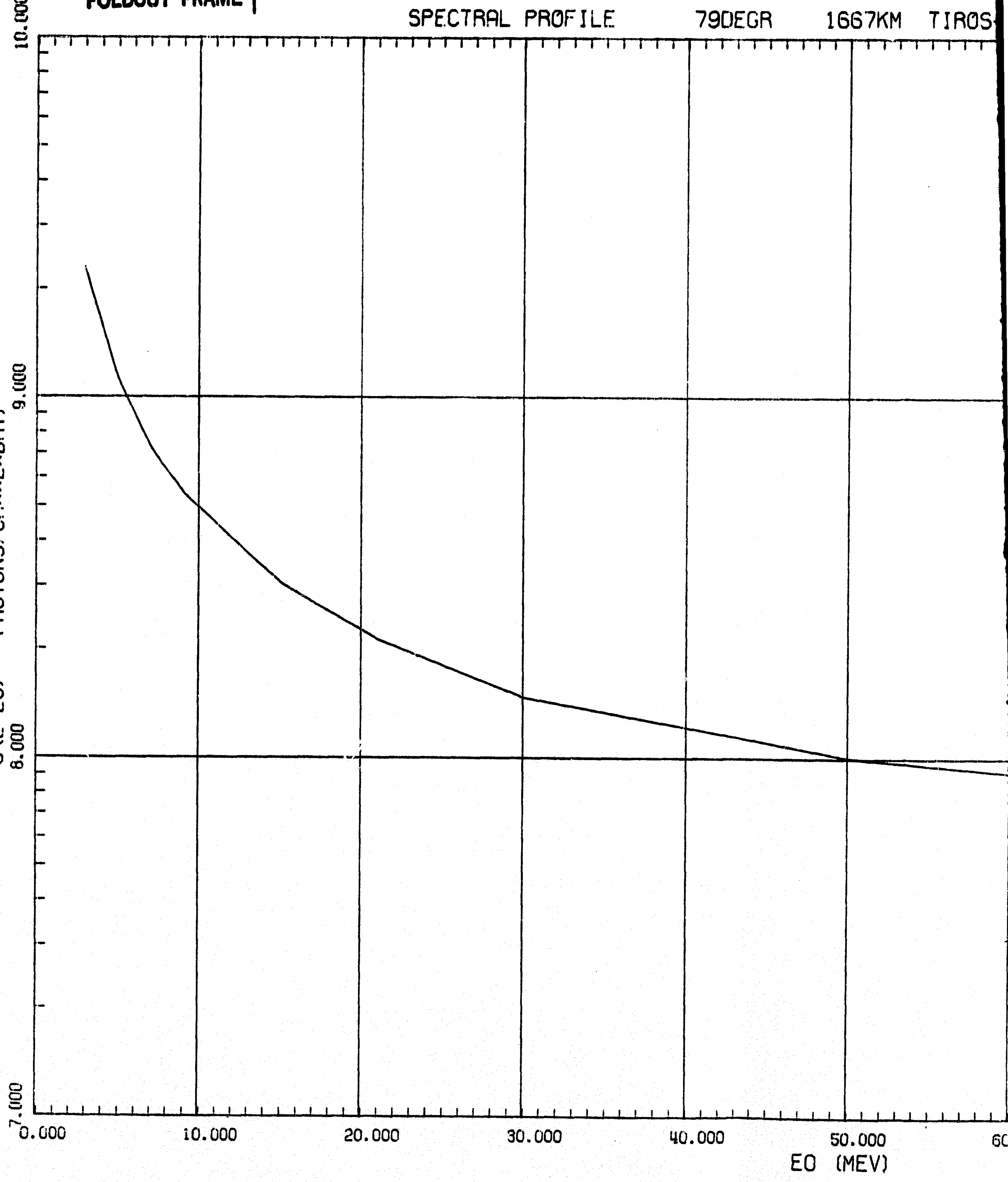
LE 79DEGR 1463KM TIROS-TOS

FOLDOUT FRAME 2

Figure 7



FOLDOUT FRAME



FOLDOUT FRAME 2

Figure 8

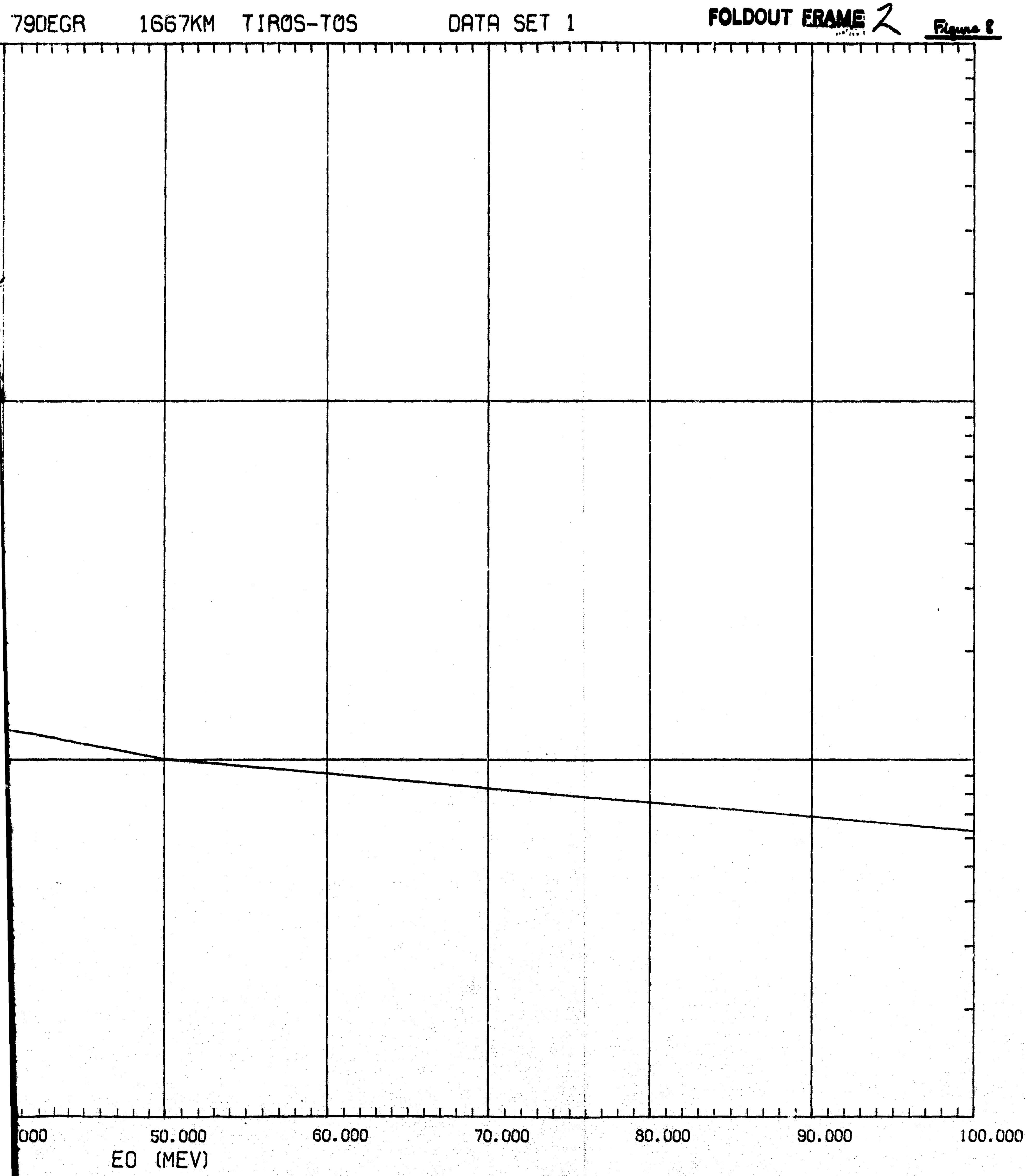
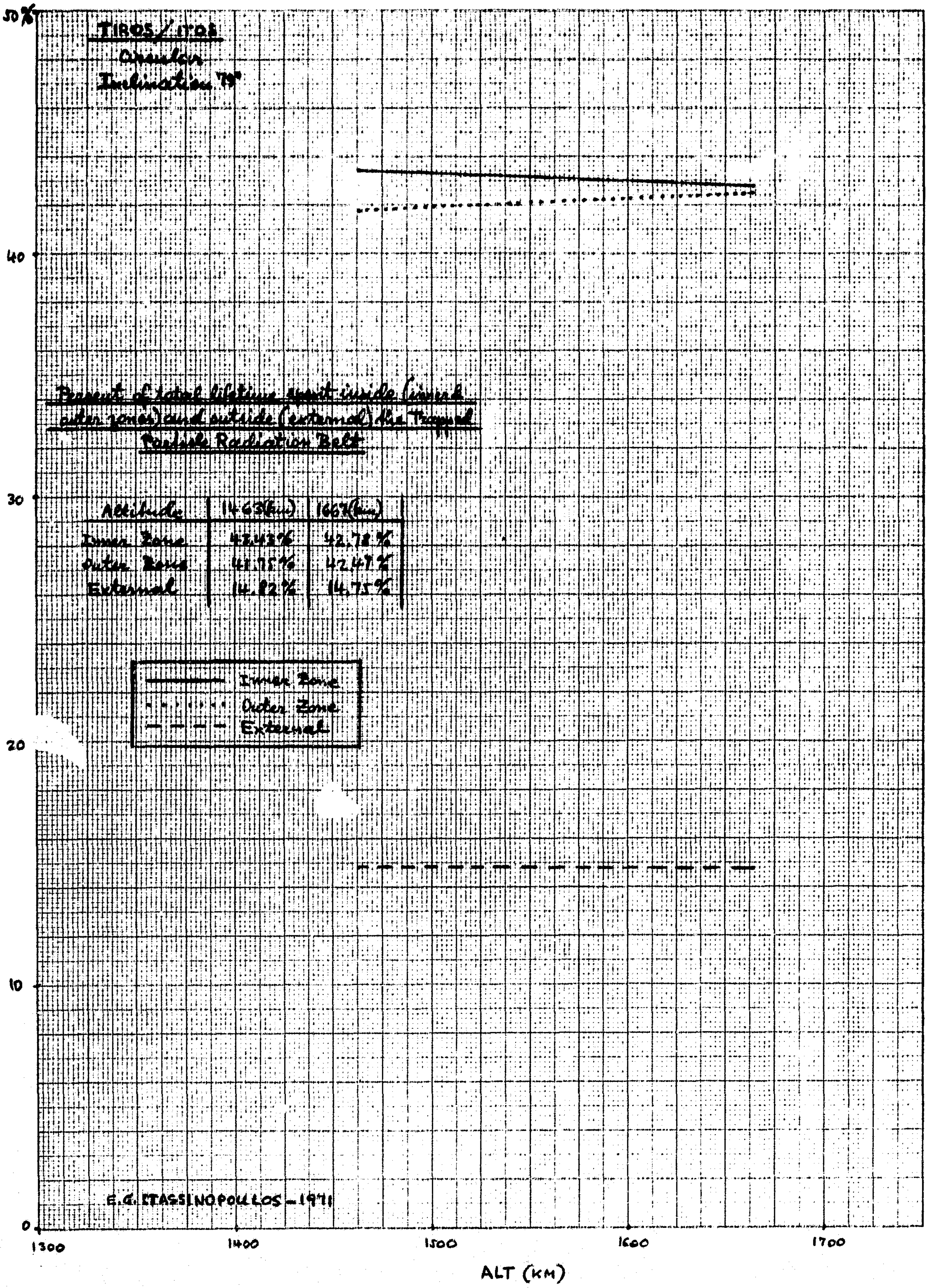
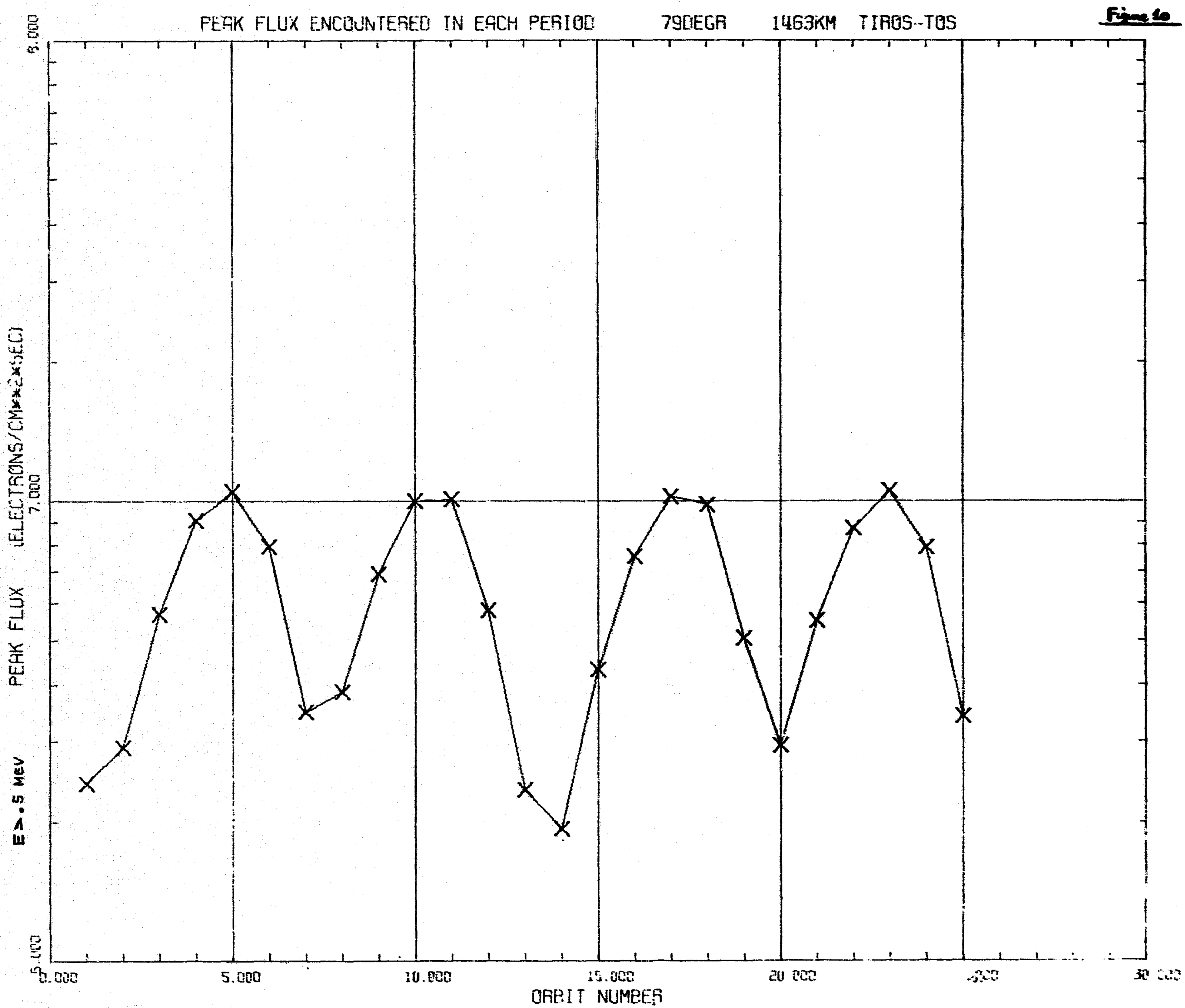
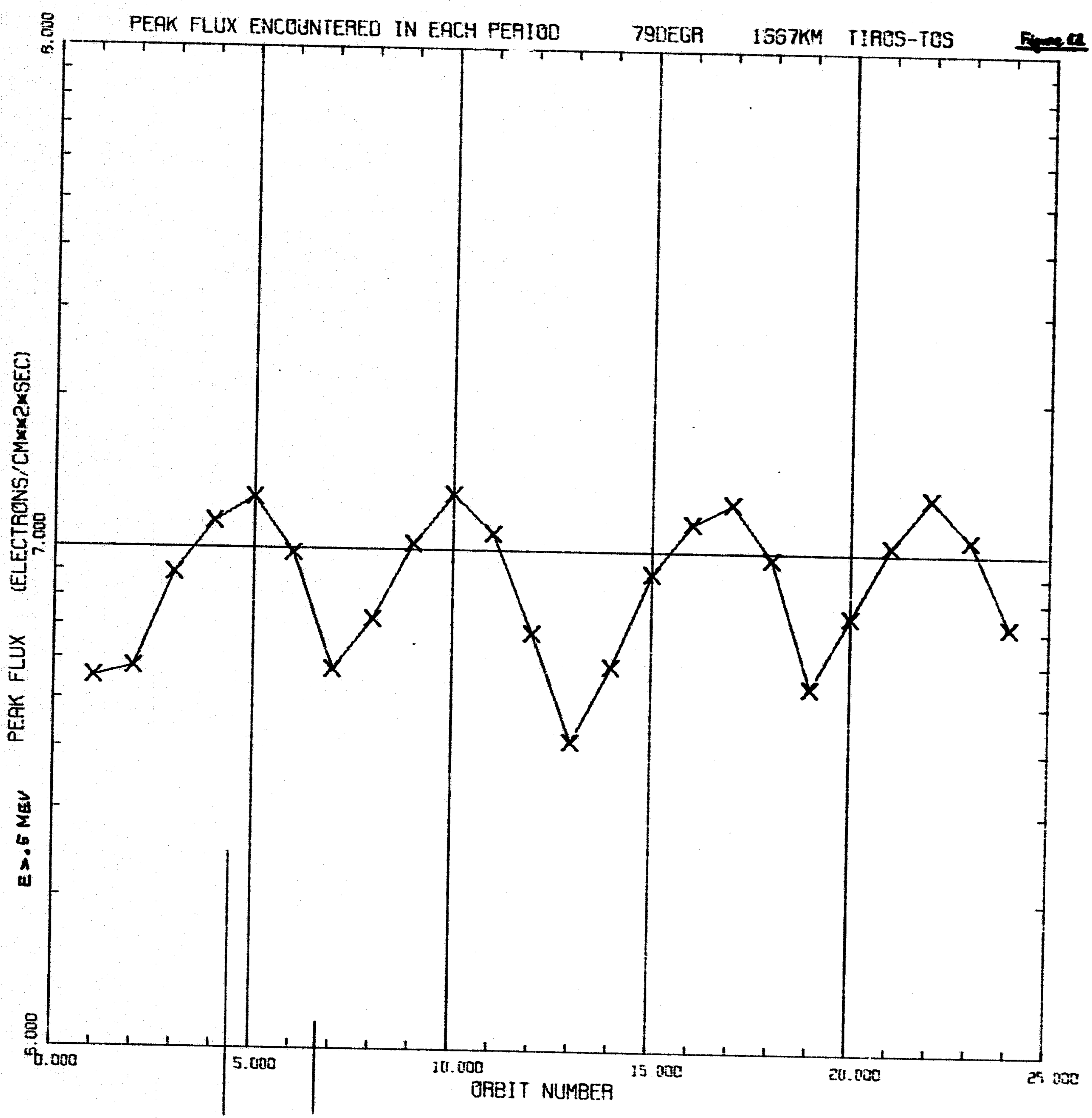


Figure 9


TIROS/ITOS
Circular
Inclination 79°
Percent of total lifetime spent inside (inner & outer zones) and outside (external) the Trapped Particle Radiation Belt
Altitude | 1463(km) | 1667(km)
Inner Zone | 43.43% | 42.78%
Outer Zone | 41.75% | 42.47%
External | 14.82% | 14.75%
Inner Zone
Outer Zone
External
E.G. STASSINOPOULOS - 1971
50%
40
30
20
10
0
1300
1400
1500
1600
1700
ALT (KM)


PEAK FLUX ENCOUNTERED IN EACH PERIOD 79DEGR 1463KM TIROS-TOS
Figure 6
8.000
7.000
6.000
PEAK FLUX (ELECTRONS/CM**2*SEC)
E>.5 MEV
0.000
5.000
10.000
15.000
20.000
30.000
ORBIT NUMBER



PEAK FLUX ENCOUNTERED IN EACH PERIOD 79DEGR 1567KM TIROS-TOS
Figure 42
8.000
7.000
6.000
PEAK FLUX (ELECTRONS/CM**2*SEC)
E>.5 MEV
0.000
5.000
10.000
15.000
20.000
25.000
ORBIT NUMBER

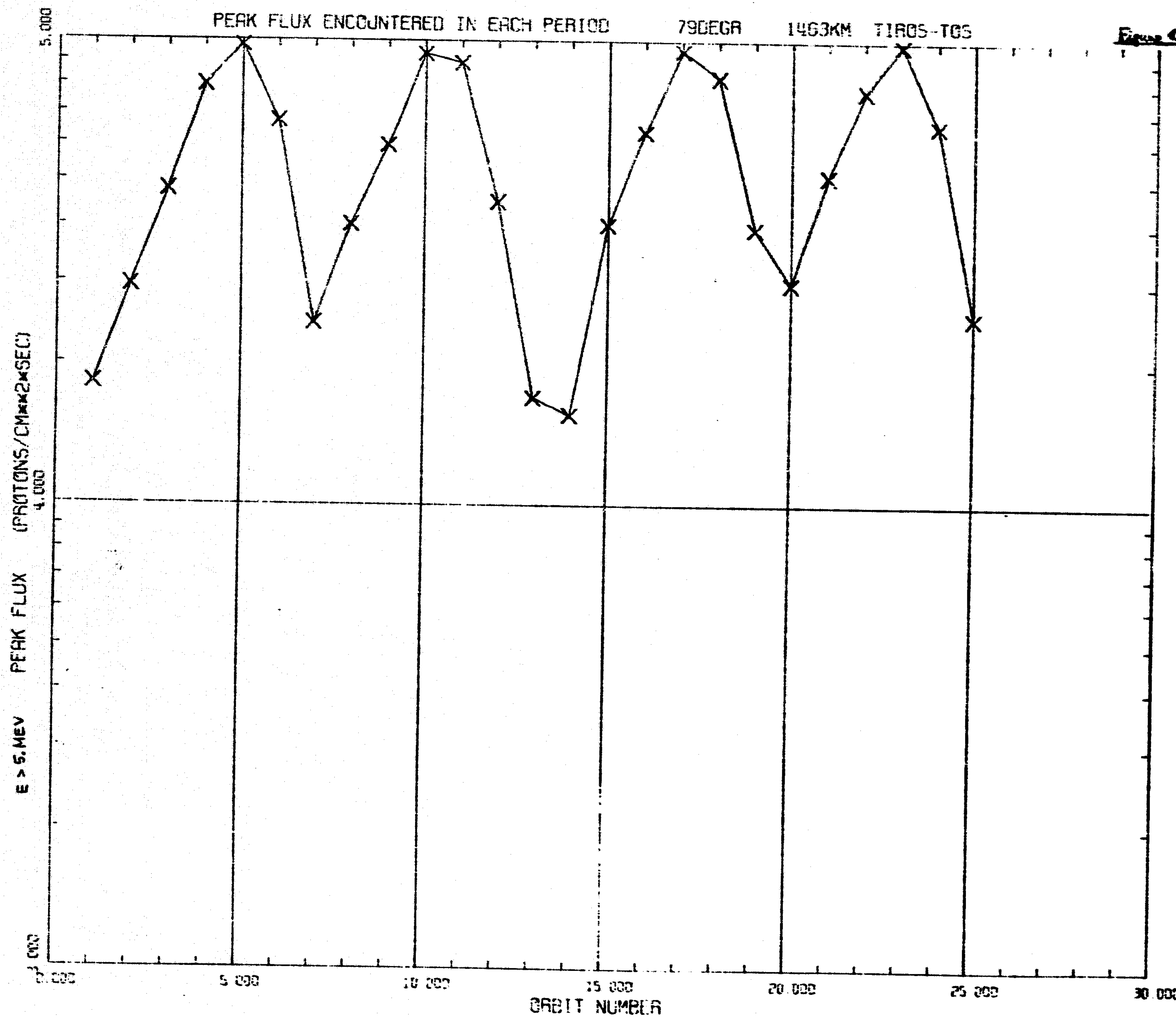
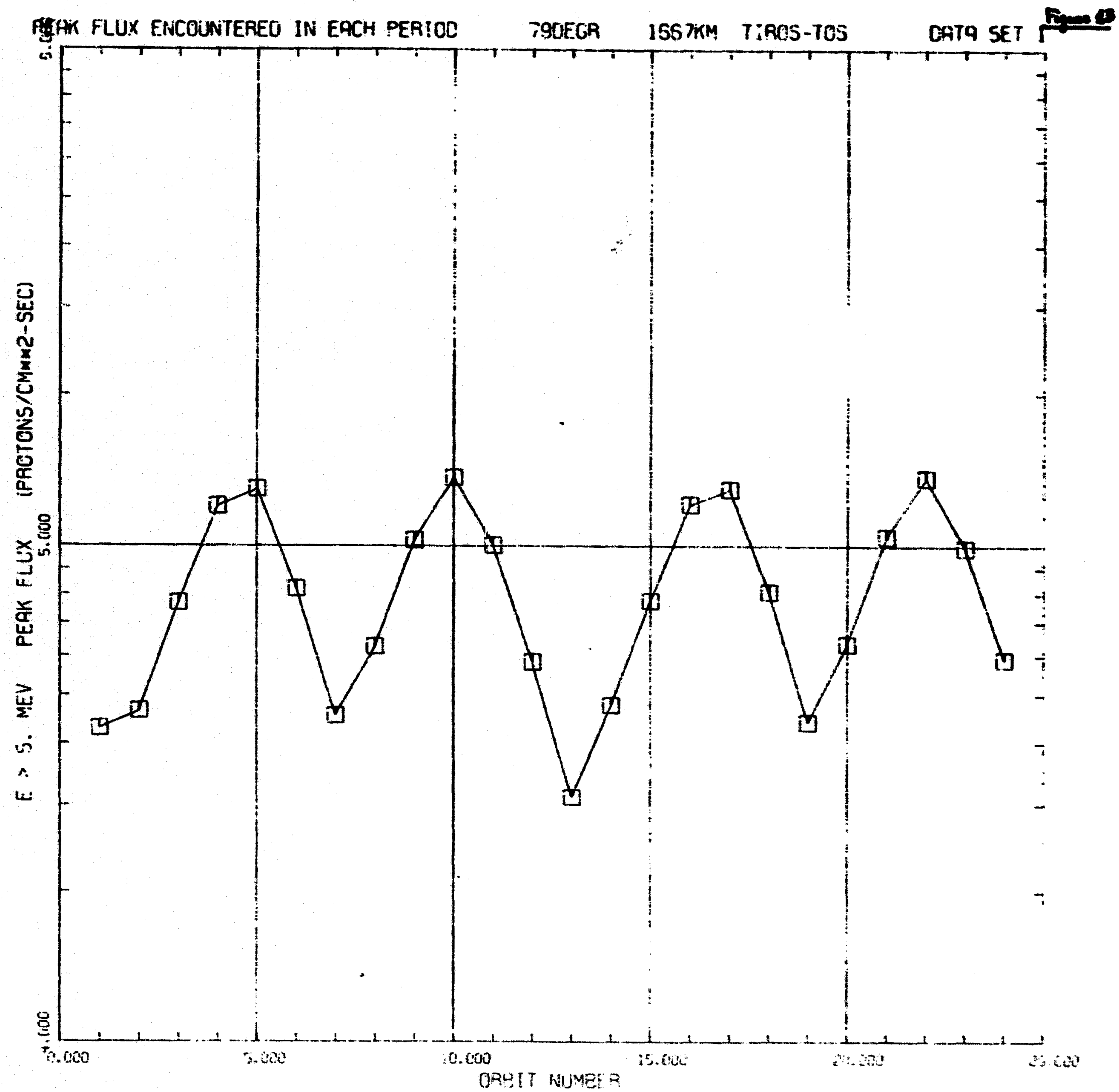
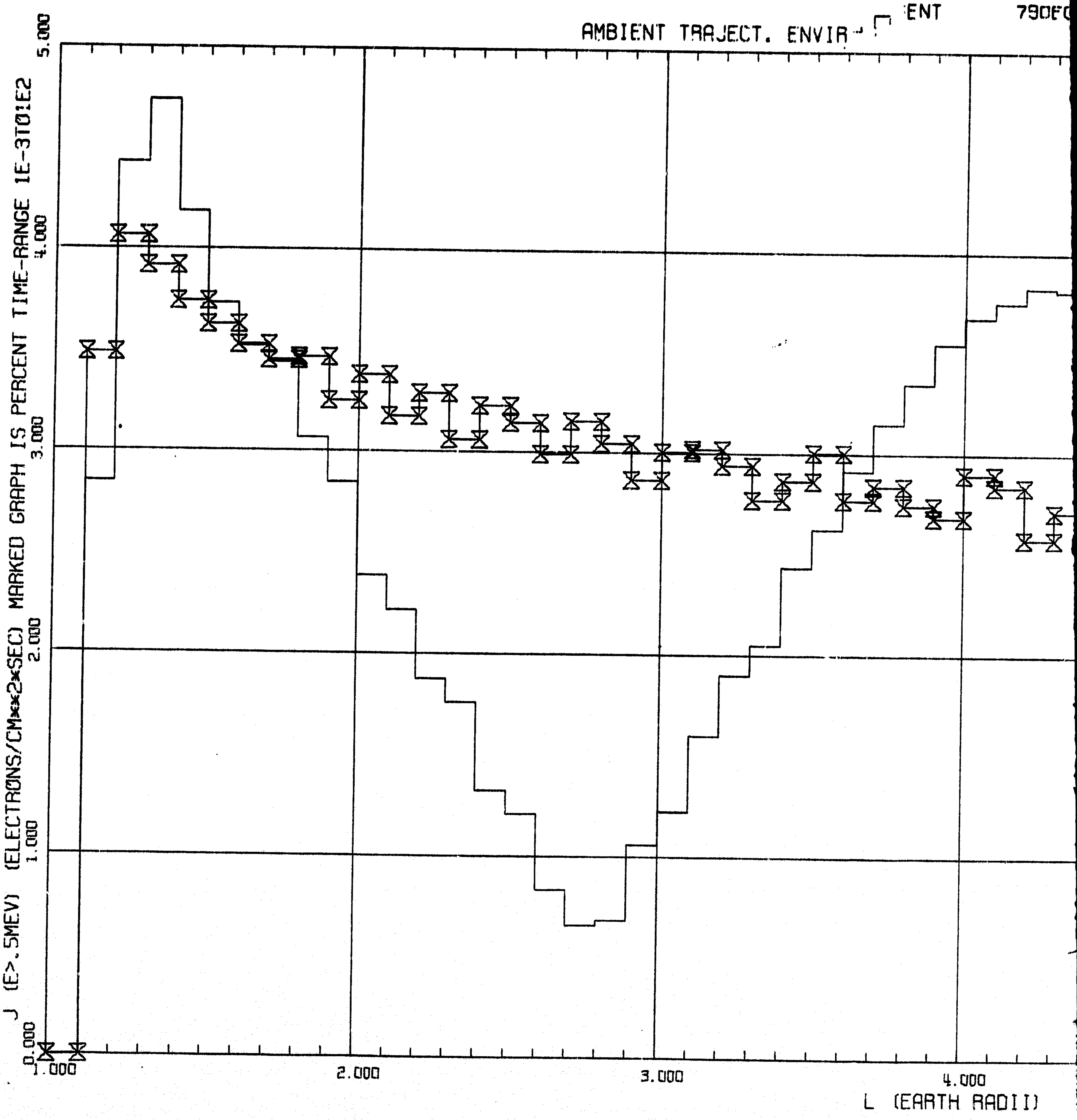

PEAK FLUX ENCOUNTERED IN EACH PERIOD 79DEGR 1463KM TIROS-TOS
E > 5.MEV PEAK FLUX (PROTONS/CM**2*SEC)
5.000
4.000
3.000
0.000
5.000
10.000
15.000
20.000
25.000
30.000
ORBIT NUMBER

Figure 42

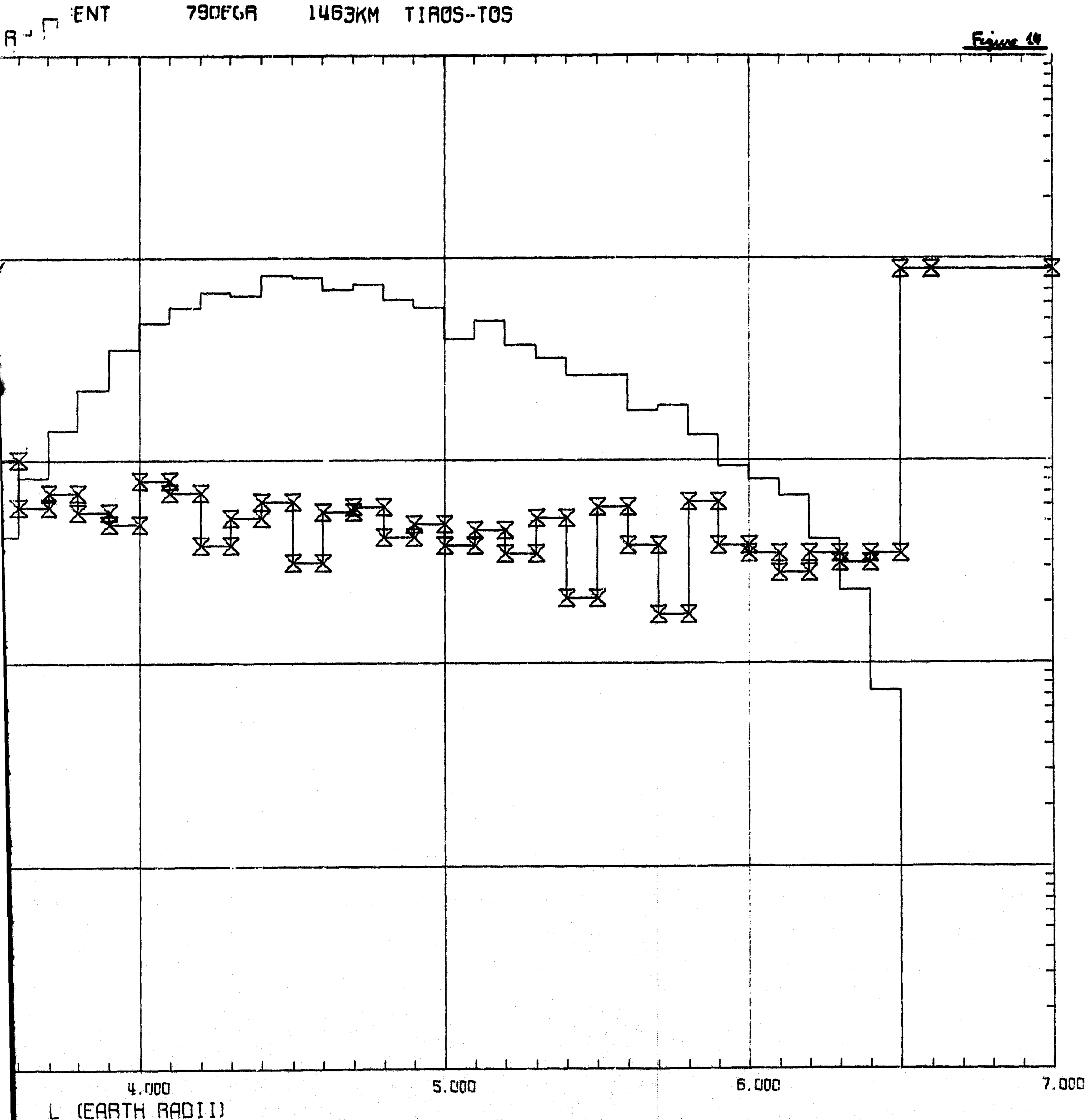

PEAK FLUX ENCOUNTERED IN EACH PERIOD 79DEGR 1567KM TIROS-TOS DATA SET
Figure 43
E > 5. MEV PEAK FLUX (PROTONS/CM**2-SEC)
5.000
5.000
4.000
0.000
5.000
10.000
15.000
20.000
25.000
ORBIT NUMBER

FOLDOUT FRAME

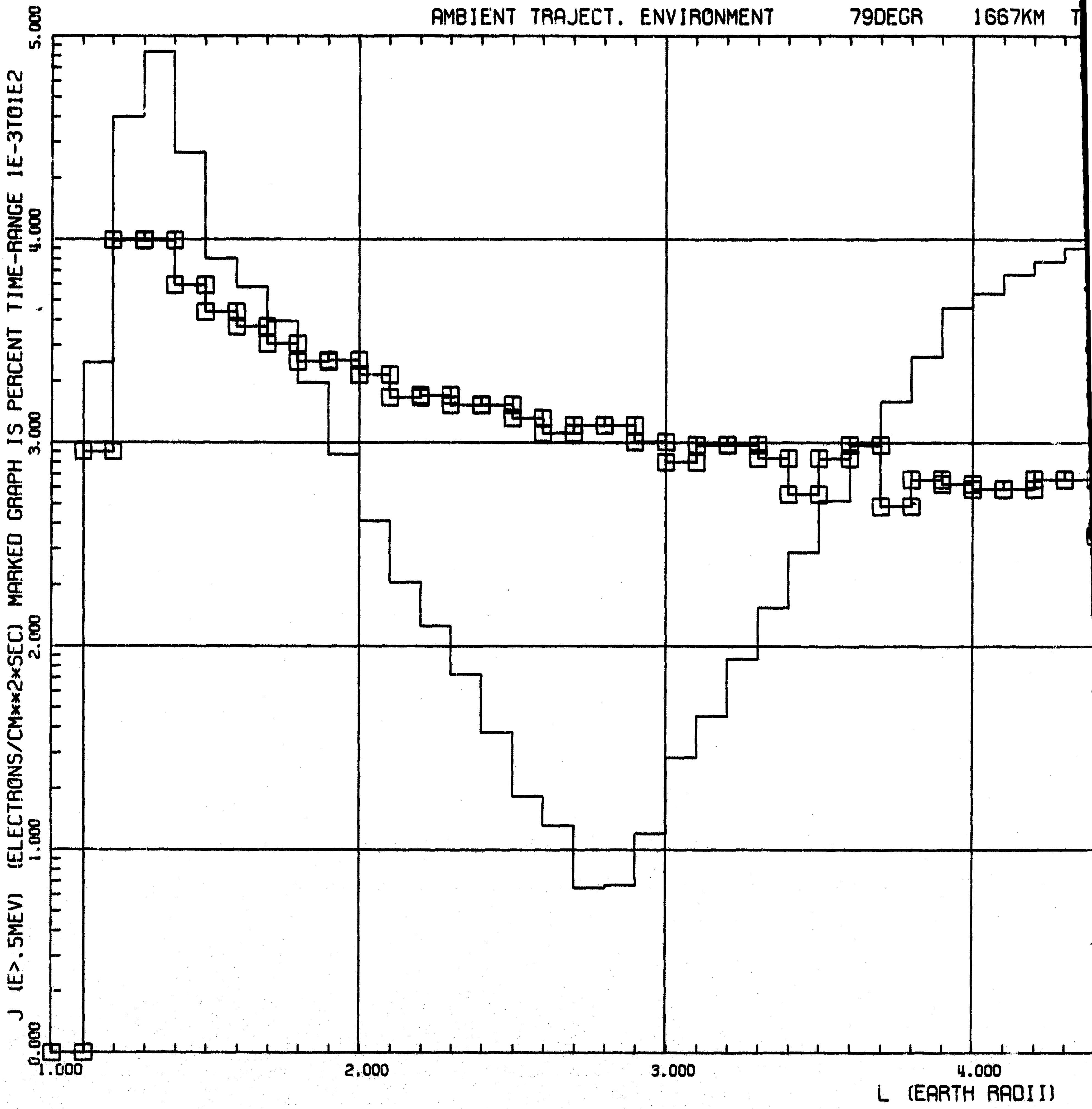


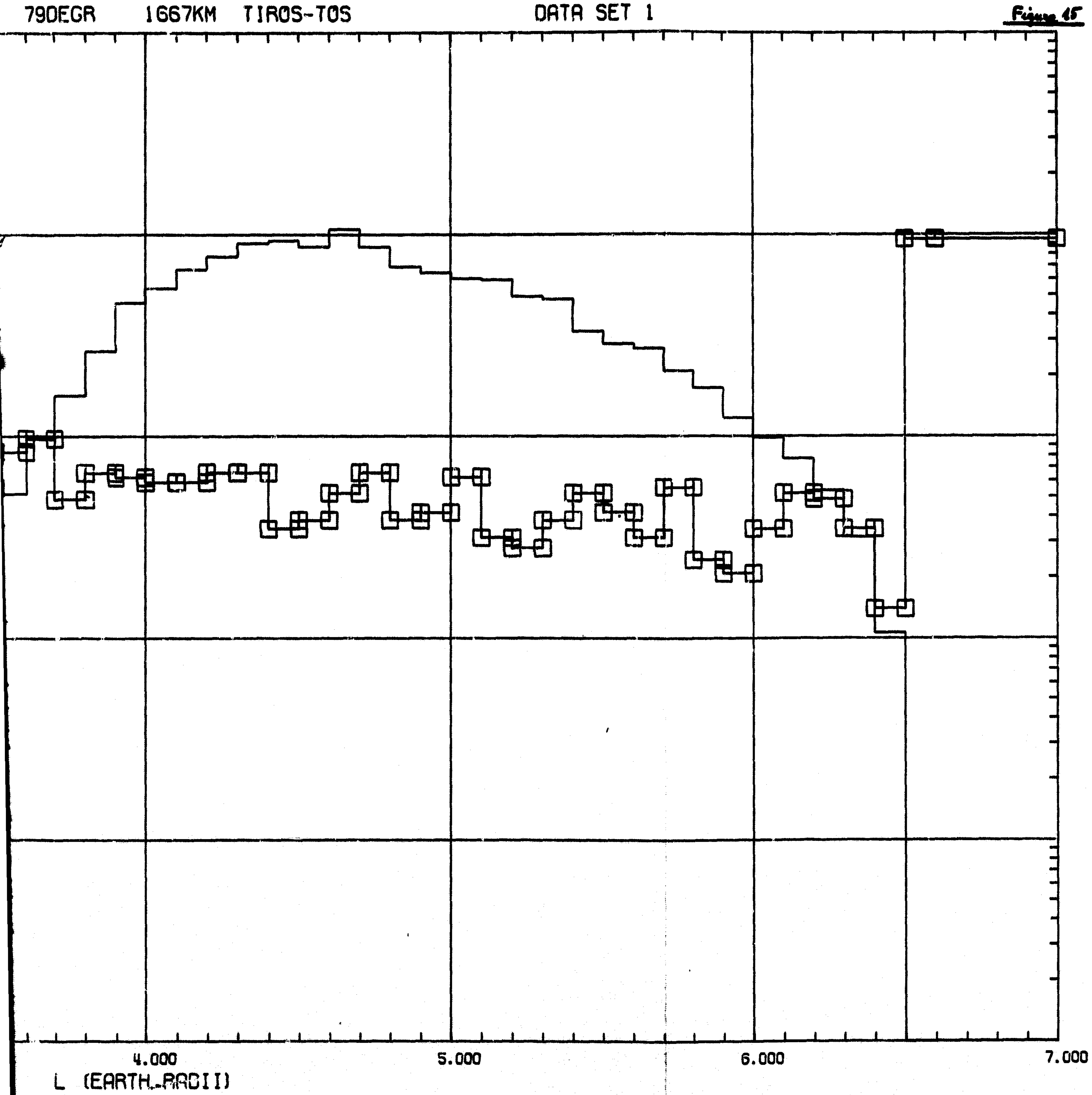
FOLDOUT FRAME 2

Figure 14



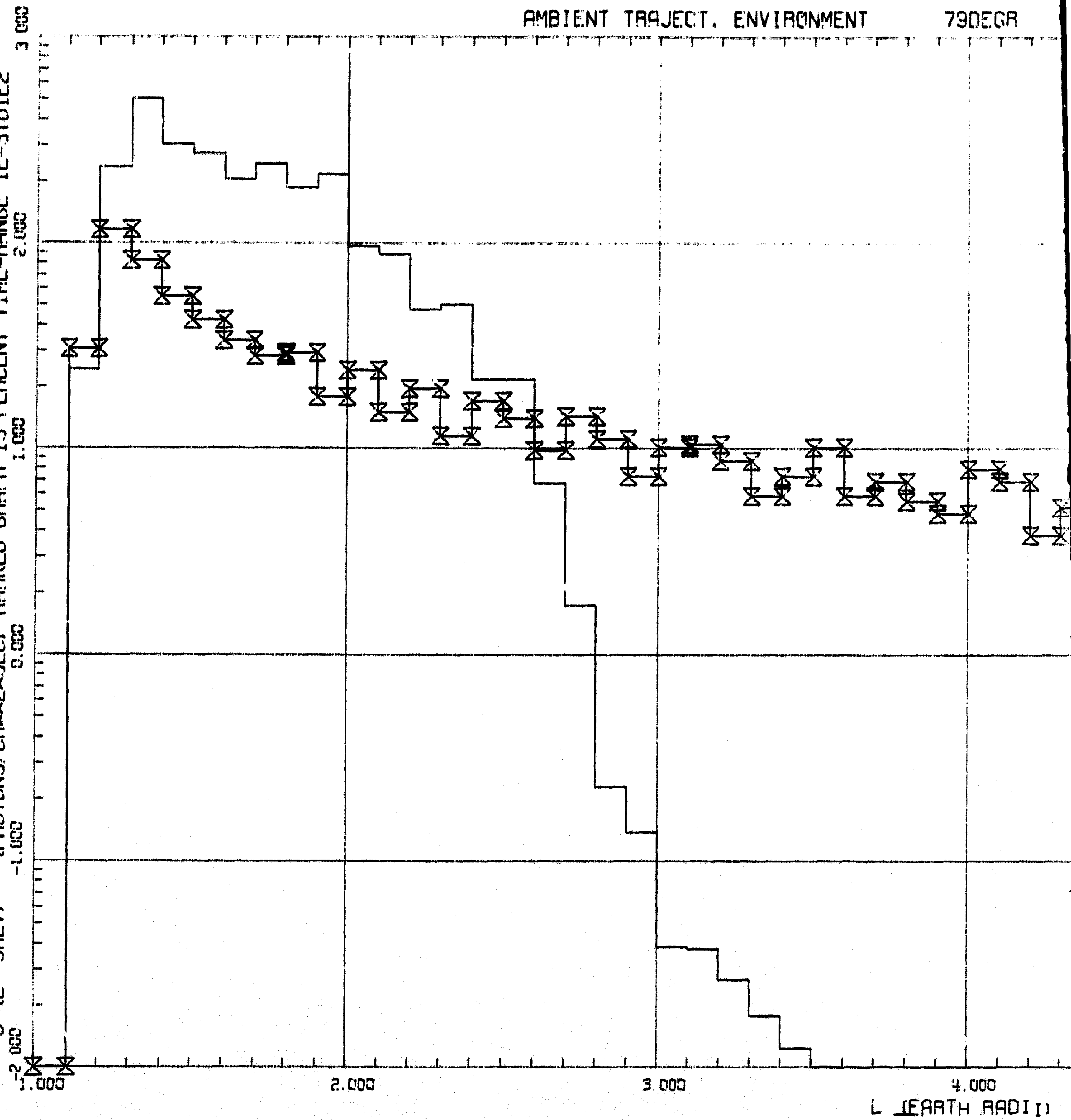
FOLDOUT FRAME



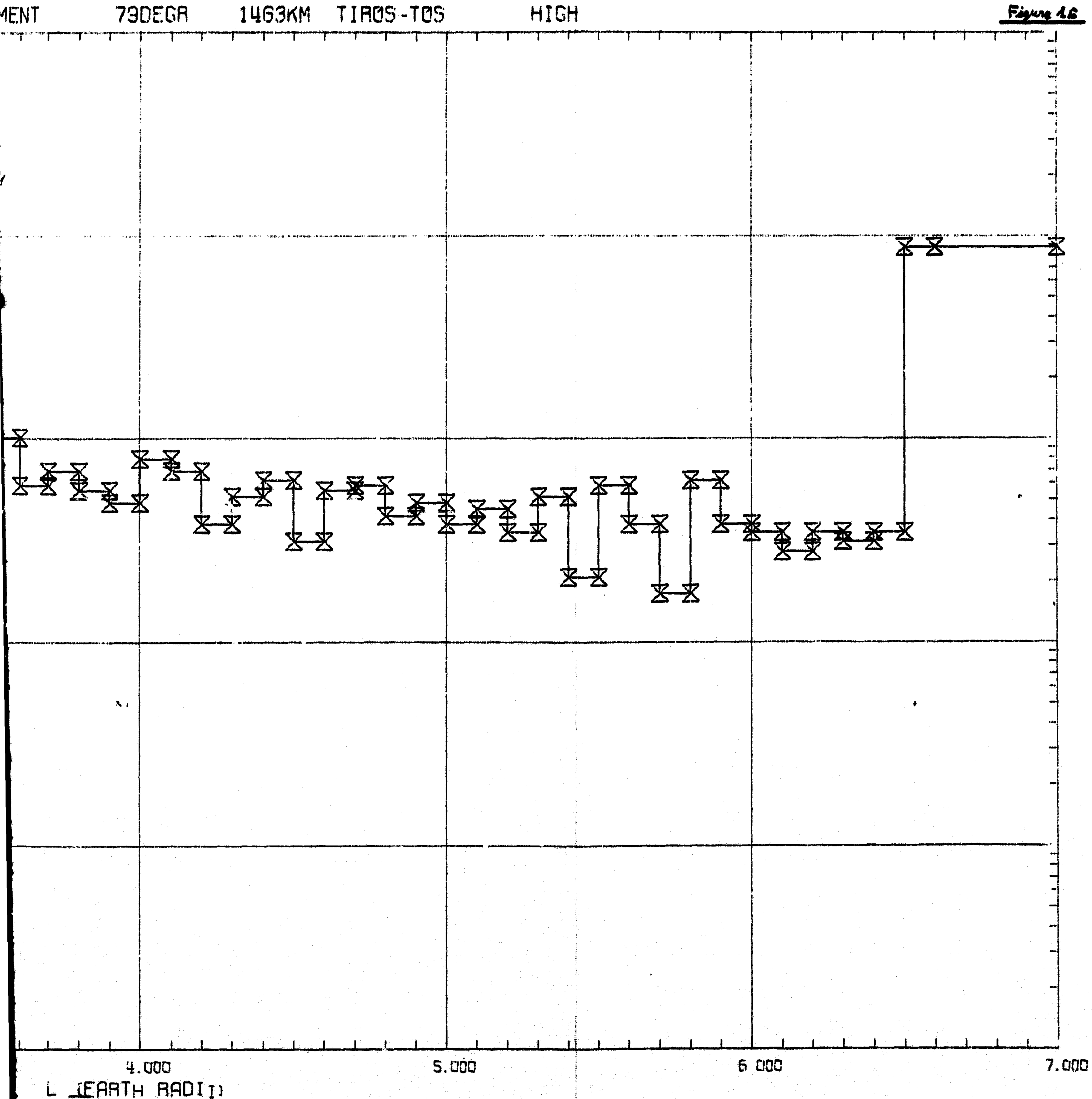


79DEGR 1667KM TIROS-TOS
DATA SET 1
Figure 45
4.000
5.000
6.000
7.000
L (EARTH RADII)

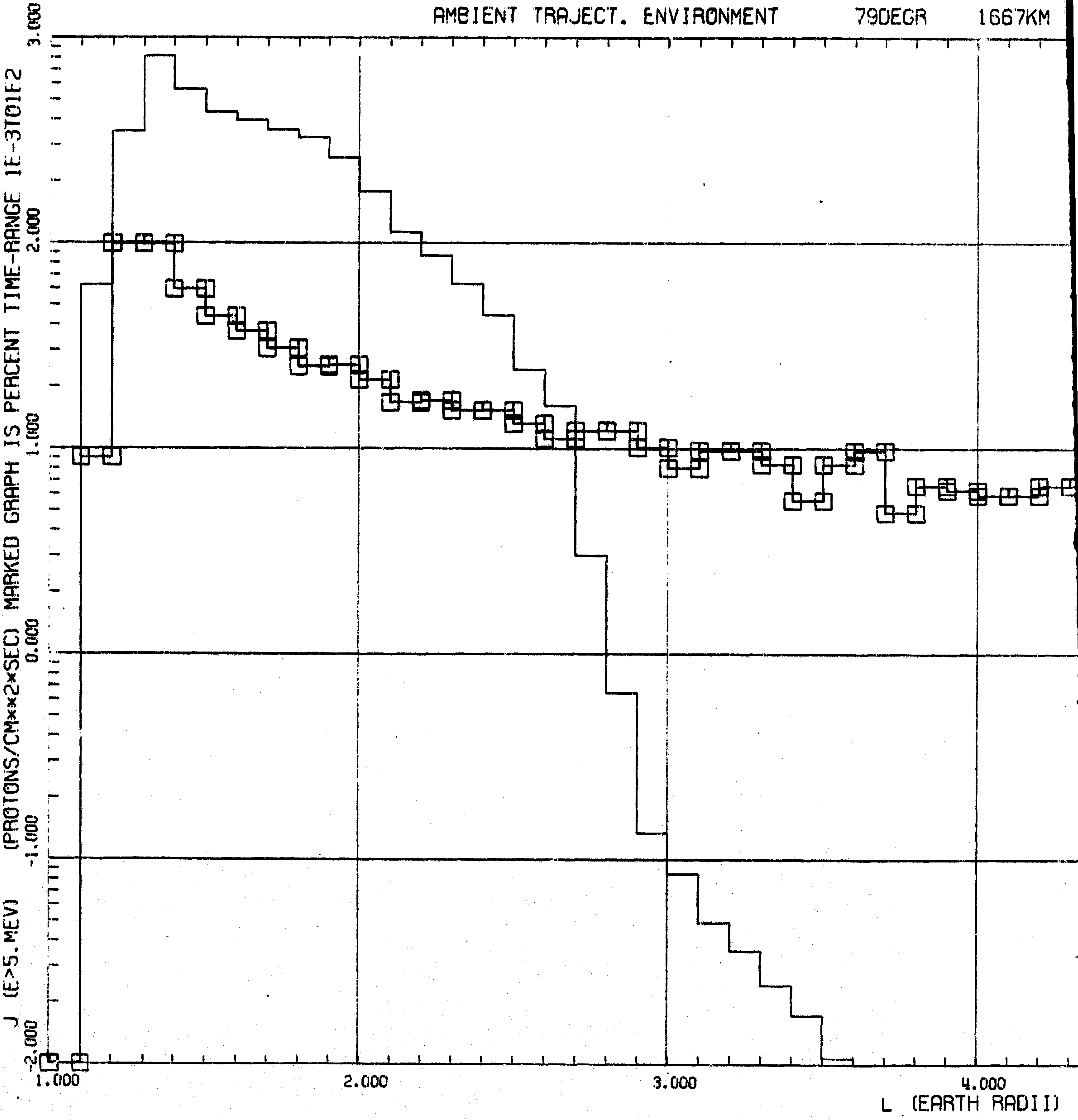
FOLDOUT FRAME



FOLDOUT FRAME 2



FOLDOUT FRAME



FOLDOUT FRAME 2

79DEGR 1667KM TIROS-TOS HIGH DATA SET 1

Figure 17