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NATURAL ENVIRONMENT CRITERIA FOR THE NASA HIGH ENERGY ASTRONOMY OBSERVATORY (HEAO)

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Aero-Astrodynamics Laboratory

March 25, 1971

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16. ABSTRACT

This document provides natural environment criteria for the NASA HEAO Program with emphasis on the 1974-1978 time period. Information in the disciplinary areas of atmospheric and ionospheric properties, radiation, solar cycle predictions, geomagnetic field, astrodynamic constants, and meteoroids is given for the region of space that is within 1000 km from the earth's surface. Extensive use has been made of the technical contributions and review comments furnished by personnel at the Marshall Space Flight Center, Lewis Research Center, and other NASA Centers and government agencies.

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TO Recipients

FROM Chairman, HEAO Task Team, PD-AP
Marshall Space Flight Center

SUBJECT Natural environment criteria for the High Energy Astronomy Observatory

This document provides an approved set of natural environment criteria for use in studies related to the NASA High Energy Astronomy Observatory Program.

Contractual work begun before the distribution of this document should not be altered on the basis of revised data contained herein (or in the supporting documents) without prior approval of the responsible NASA contracting officer's representative. If the data in this document and the referenced supporting documents are not of sufficient detail for application to a design or operational planning problem, the user should submit a request through appropriate MSFC contracting office and HEAO task team channels to the Aerospace Environment Division (S&E-AERO-Y) of the Aero-Astrodynamics Laboratory.

This document will be revised when warranted by new knowledge on the natural environment criteria or the HEAO mission definition.

R. D. Stewart

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SUMMARY

This document provides natural environment criteria for the NASA HEAO Program with emphasis on the 1974-1978 time period. Information in the disciplinary areas of atmospheric and ionospheric properties, radiation, solar cycle predictions, geomagnetic field, astrodynamic constants, and meteoroids is given for the region of space that is within 1000 km from the earth's surface. Extensive use has been made of the technical contributions and review comments furnished by personnel at the Marshall Space Flight Center, the Lewis Research Center, and other NASA Centers and government agencies.

INTRODUCTION

The natural environment and physical standards to be used for the NASA High Energy Astronomy Observatory (HEAO) studies are included in this document. Two supporting documents have been published: "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Space Vehicle Development (1969 Revision)," TM X-53872 (Second Printing), March 15, 1970 and "Space Environment Criteria Guidelines for Use in Space Vehicle Development (1969 Revision)," NASA TM X-53957 (Second Edition), August 26, 1970, plus addendums to these documents.

Natural environment conditions encountered by spacecraft and launch vehicles are important factors in studies relative to design, pre-flight mission planning, engineering performance, and scientific experiment design and evaluation. This document provides such criteria for the NASA HEAO Program.

The data contained in this document are reviewed on a continuing basis and revisions or amendments will be published as necessary.

Principal contributors to the various sections given in this report are identified by disciplinary area in references I-1 and II-1.

I. PRE-LAUNCH, LAUNCH AND INFLIGHT ENVIRONMENT

This section provides natural environment criteria that should be used in studies related to the design and operation of the NASA High Energy Astronomy Observatory (HEAO) during pre-launch, launch, and inflight phases. Values of natural environment parameters not specifically defined below may be obtained from material given in references I-1 and I-2.

1.1 Gas Properties

1.1.1 Nominal Gas Properties

The Cape Kennedy Reference Atmosphere (CKRA) given in Table 14.10 of reference I-1 should be used as nominal criteria for surface-to-orbit trajectory analyses. This atmosphere is available from the MSFC Computation Laboratory as a subroutine entitled "Computer Subroutine PRA-63."

1.1.2 Extreme Gas Properties

For problems requiring extremes of pressure, temperature, and density versus altitude, the coefficients of variation (CV) from Table 14.8 of reference I-1 and the mean values from Table 14.10 of reference I-1 should be applied as follows:

$$\text{Maximum Parameter} = \text{CKRA}\left[1 + \frac{3\ \text{CV}}{100}\right] \tag{1}$$

$$\text{Minimum Parameter} = \text{CKRA}\left[1 - \frac{3\ \text{CV}}{100}\right] . \tag{2}$$

These extreme envelopes (mean ±3 standard deviations) must be used with caution. For example, extreme values of temperature, pressure, and density at a given altitude should not be used simultaneously (see paragraph 1.1.4). In addition, the extremes of one parameter cannot exist for the entire profile at a given time. However, if one is dealing with atmospheric extremes of pressure, temperature, and density independent of each other at discrete altitudes and if that analysis does not depend on atmospheric conditions at other altitude levels, then the extreme values derived from equations (1) and (2) may be used.

1.1.3 Extreme Profiles of Gas Properties

For problems requiring the structure of an extreme density versus altitude profile, such as in aerodynamic heating analyses, the hot and cold atmospheres given in Table 14.9 of reference I-1 should be used.

1.1.4 Thermodynamic Quantities Associated with Extreme Pressure, Temperature and Density Values

For problems requiring a knowledge of the two atmospheric variables that are associated with a third extreme variable at discrete altitudes, the functions given below may be used. Values for the coefficients of variation and correlation coefficients should be obtained from Table 14.8 of reference I-1 and the mean atmospheric values from Table 14.10 of reference I-1.

	For Extreme Density	For Extreme Temperature	For Extreme Pressure
$P_{assoc.} =$	$\bar{P}\left[1 \pm \left\{M(\sigma_P/\bar{P})r(P\rho)\right\}\right]$	$\bar{P}\left[1 \pm \left\{M(\sigma_P/\bar{P})r(PT)\right\}\right]$	
$T_{assoc.} =$	$\bar{T}\left[1 \pm \left\{M(\sigma_T/\bar{T})r(\rho T)\right\}\right]$		$\bar{T}\left[1 \pm \left\{M(\sigma_T/\bar{T})r(PT)\right\}\right]$
$\rho_{assoc.} =$		$\bar{\rho}\left[1 \pm \left\{M(\sigma_\rho/\bar{\rho})r(\rho T)\right\}\right]$	$\bar{\rho}\left[1 \pm \left\{M(\sigma_\rho/\bar{\rho})r(P\rho)\right\}\right]$

Use + sign when extreme parameter is maximum.
Use - sign when extreme parameter is minimum.

In these equations, "M" denotes the multiplication factor to give the desired deviation. The values of M for the normal distribution and the associated percentile levels are as follows:

	M			Percentile
mean	-3	standard deviations		0.135
mean	-2	standard deviations		2.275
mean	-1	standard deviations		15.866
mean	±0	standard deviations	= median	50.000
mean	+1	standard deviations		84.134
mean	+2	standard deviations		97.725
mean	+3	standard deviations		99.865

1.2 Winds

For launch and on-pad stay-time capability of the HEAO plus launch vehicle configuration, the following ground and inflight wind values shall be employed as desired goals. As soon as practicable, the contractor shall establish applicable ground and inflight wind operational constraints for the HEAO/launch vehicle configuration. Risk of exceedances for the expected operational modes may then be determined.

1.2.1 Ground Winds

To provide a reasonable launch and on-pad stay-time capability for the HEAO plus launch vehicle, the following ground wind speed values from any azimuth should be used. For launch, the 5 percent risk for the windiest hour exposure period as given in Table 5.2.13 of reference I-1 should be used. While the vehicle is free-standing on the pad and is protected by the launch pad service structure (including possible structural tie off or dampers), the wind speed profile associated with the expected on-pad exposure time of the HEAO as given in Table 5.2.16 of reference I-1 should be used. This peak wind speed profile shall be used to calculate vehicle on-pad base overturning moments and vortex shedding loads. Calculations to establish the launch vehicle plus HEAO ground wind constraints, based on the existing structure capabilities, should be in accordance with the peak wind speed profile shapes as defined in paragraph 5.2.5.2 of reference I-1 for which a tabulated listing as a function of a reference height wind speed is available upon request to the MSFC Aerospace Environment Division (S&E-AERO-Y) of the Aero-Astrodynamics Laboratory.

1.2.2 Inflight Winds

1.2.2.1 Rigid Body Studies

The HEAO launch vehicle inflight wind analysis should be conducted with respect to the 95 percentile directional wind speed envelope as given in Tables I-1, I-2, and I-3. Vehicle response should be calculated for all flight azimuths anticipated for the launch of the HEAO. Since the HEAO will be launched only from Cape Kennedy, the wind shears which should be used with the directional wind speed envelope are given in Tables I-4 and I-5.

For calculation involving the use of a biased trajectory, if desired for the enhancement of launch probability, data on mean wind speed profile as a function of launch azimuth given in reference I-2 should be used.

A design discrete gust value shall be associated with the above steady-state design wind speed and wind shears. Discrete gusts are specified in an attempt to represent, in a physically reasonable manner for engineering studies, characteristics of small-scale motions associated with vertical wind velocity profiles. Gust structure is quite complex. For use in rigid body vehicle design studies, discrete gusts are usually idealized to facilitate their use because of their complexity. Gusts are also referred to as embedded jets or singularities in the vertical profile of the wind. By definition, a gust is a wind speed in excess of a defined steady-state value; therefore, gusts are used in vehicle design studies by superimposing them on the steady-state wind profiles. The discrete gust to be used in the rigid body design studies consists of a one-minus-cosine shape with a 9 m sec amplitude and a thickness (depth) of 60 to 300 meters (see Section 5.3.8, reference I-1).

To determine the gust thickness, a series of gusts will have to be calculated with each gust having a different thickness. Loads will then be calculated, and the design value of the gust depth will be determined by selecting the one associated with the most adverse situation.

In the construction of a synthetic wind speed profile, the degree of correlation between the wind parameters must be taken into account. This can be accomplished by multiplying the shears (wind speed changes) and the one-minus-cosine discrete gust by a factor of 0.85 before constructing the synthetic wind profile. This is equivalent, as an engineering approximation, to taking the combined 1 percent risk gust and shear combination rather than the separate addition of the 1 percent risk values for the gusts and shears in a perfectly correlated manner. A series of synthetic wind speed profiles will have to be constructed, with each profile having a different reference point at which the design shear envelope intersects the design wind speed profile envelope. Loads will be calculated, and the design synthetic wind speed profile will be determined by selecting the one associated with the most adverse loading conditions. The specific details concerning the construction of design synthetic wind speed profiles for use in the HEAO design are given in Section 5.3.9 of reference I-1.

The synthetic wind speed profile without gust will be used for preliminary studies if aeroelastic data are not available. Static, aeroelastic, and buffeting loads must also be considered.

1.2.2.2 Elastic Body Studies

The synthetic wind speed profile without gust can be used in elastic body calculations. The loads resulting from the synthetic wind profile can be calculated with a rigid or elastic body trajectory. Static, aeroelastic and buffeting loads must also be considered.

The power spectrum to be used in elastic body studies is given by the following expression:

$$E(k) = \frac{683.4\ (4000\ k)^{1.62}}{1 + 0.0067\ (4000\ k)^{4.05}}$$

where the spectrum E(k) is defined so that integration over the domain $0 \leqq k \leqq \infty$ yields the variance of the turbulence. In this equation E(k) is the power spectral density ($m^2 sec^{-2}$/(cycles per meter)) at wave number k($meter^{-1}$). The associated design turbulence loads are obtained by multiplying the load standard deviations by a factor of three. The loads obtained from application of this turbulence power spectrum should be added to the rigid vehicle loads resulting from the use of the synthetic wind speed profile (given in paragraph 1.2.2.1). This wind shear/ spectrum combination will result in a 1 percent risk condition for the elastic vehicle studies, when used with the design steady-state wind speed envelope values.

1.3 Additional Information

Environment criteria guideline data on those aspects of the atmosphere (surface to 90 km altitude) not specified in this section may be obtained from reference I-1. If additional criteria (for example, selection of detailed wind profiles for final verification analysis of vehicle response capabilities) are needed for a particular HEAO study, then a request should be made through the appropriate NASA contracting officer's representative to the MSFC Aerospace Environment Division (S&E-AERO-Y) of the Aero-Astrodynamics Laboratory.

TABLE I-1. Envelopes of Idealized Monthly Wind Component (Head, Tail, Right-Cross and Left-Cross) Frequency Distributions, for 5 to 6 Kilometers Altitude, as a Function of Flight Azimuths, Cape Kennedy, Florida, Based on Windiest Monthly Reference Period Concept [I-3].

Azimuth*	Percentiles 30%	50%	75%	90% (meters/second)	95%**	99%
0	1	2	6	10	14	22
15	1	2	5	8	11	18
30	1	2	4	7	9	15
45	1	3	4	7	9	13
60	1	3	5	7	9	12
75	1	3	6	8	9	12
90	1	3	6	8	9	12
105	1	3	5	7	9	12
120	1	2	4	6	8	12
135	1	2	3	6	8	13
150	1	2	3	6	9	15
165	1	2	4	8	11	21
180	2	5	8	16	22	35
195	5	10	17	25	30	40
210	7	12	20	28	34	46
225	11	16	24	32	39	51
240	14	19	27	36	42	53
255	16	21	29	38	44	56
270	16	21	29	38	44	56
285	15	20	27	34	41	53
300	14	19	26	34	40	48
315	9	14	22	29	35	44
330	5	10	17	24	29	35
345	2	5	10	15	19	27
360	1	2	6	10	14	22

*Direction from which wind component is blowing. Referenced clockwise from true north.

**Recommended for HEAO/Launch Vehicle analyses.

TABLE I-2. Envelopes of Idealized Monthly Wind Component (Head, Tail, Right-Cross, and Left-Cross) Frequency Distributions for 10 to 14 Kilometers Altitude, as a Function of Flight Azimuths, Cape Kennedy, Florida, Based on Windiest Monthly Reference Period Concept [I-3].

Azimuth*	Percentiles 30%	50%	75%	90%	95%**	99%
			(meters/second)			
0	2	6	14	24	31	40
15	4	7	12	19	25	32
30	4	8	12	17	21	28
45	4	8	13	18	22	30
60	4	8	14	20	24	30
75	4	7	12	18	21	26
90	0	6	13	19	22	26
105	2	4	10	17	21	26
120	2	3	7	12	16	26
135	0	1	5	10	15	27
150	0	1	4	10	15	30
165	0	1	4	13	22	45
180	1	5	12	23	33	54
195	12	20	30	40	50	66
210	17	25	36	48	58	76
225	26	33	47	57	66	86
240	34	42	56	67	73	93
255	39	46	57	68	75	97
270	41	47	56	67	74	95
285	37	44	53	65	73	89
300	31	38	49	60	69	79
315	23	31	40	51	59	68
330	15	21	31	42	50	60
345	6	11	21	33	41	50
360	2	6	14	24	31	40

*Direction from which wind component is blowing. Referenced clockwise from true north.

**Recommended for HEAO/Launch Vehicle analyses.

TABLE I-3. Envelopes of Idealized Monthly Wind Component (Head, Tail, Right-Cross and Left-Cross) Frequency Distributions for 18 to 20 Kilometers Altitude, as a Function of Flight Azimuths, Cape Kennedy, Florida, Based on Windiest Monthly Reference Period Concept [I-3].

	Percentiles					
Azimuth*	30%	50%	75%	90%	95%**	99%
	(meters/second)					
0	1	2	5	8	10	13
15	3	4	6	8	9	13
30	5	6	8	10	11	14
45	8	9	11	13	14	16
60	10	11	12	14	16	18
75	10	11	13	15	17	19
90	10	12	14	16	17	19
105	10	12	12	15	17	18
120	7	9	10	12	14	16
135	5	7	9	11	12	14
150	2	4	6	8	9	13
165	1	2	3	6	8	14
180	1	2	5	9	11	18
195	2	4	9	14	18	24
210	5	7	12	17	22	31
225	7	11	16	22	26	36
240	8	13	18	25	30	40
255	10	14	20	27	32	42
285	10	14	19	24	29	40
300	11	15	19	23	27	34
315	9	12	17	20	23	27
330	5	8	13	16	19	22
345	2	4	8	10	13	16
360	1	2	5	8	10	13

*Direction from which wind component is blowing. Reference clockwise from true north.

**Recommended for HEAO/Launch Vehicle analyses.

TABLE I-4. Idealized Envelopes of 99 Percentile Scalar <u>Buildup</u> Wind Speed Change for Various Scales of Distance and Corresponding Wind Speeds at the Top of the Layer in the 1- to 80-kilometer Altitude Region for Eastern Test Range Launch Area.

Wind Speed at Top of Altitude Layer (ms^{-1})	Wind Speed Change (ms^{-1}) for Various Scales of Distance — Scales of Distance (m): 5000	4000	3000	2000	1000	800	600	400	200	100
$\geq$ 90	65.6	59.5	52.3	43.5	34.0	29.0	23.8	17.9	11.2	6.8
80	60.4	55.5	49.7	42.0	32.7	27 7	22.7	17.0	10.6	6.5
70	56.0	51.7	47.0	40.4	31.2	26.6	21.8	16.4	10.1	6.2
60	51.3	48.5	44.5	38.6	30.0	25.6	21.1	15.8	9.8	6.0
50	46.5	45.0	41.2	36.5	28.5	24.4	20.0	15.0	9.2	5.7
40	38.5	37.7	36.8	34.9	26.5	22.6	18.5	13.8	8.6	5.3
30	28.0	27.5	26.5	24.5	20.8	17.8	14.5	10.8	6.7	4.1
20	17.6	17.3	16.6	15.8	14.6	12.5	10.2	7.0	4.7	2.9

TABLE I-5. Idealized Envelopes of 99 Percentile Scalar <u>Backoff</u> Wind Speed Change for Various Scales of Distance and Corresponding Wind Speeds at the Top of the Layer in the 1- to 80-Kilometer Altitude Region for Eastern Test Range Launch Area.

Wind Speed at Top of Altitude Layer (ms^{-1})	Wind Speed Change (ms^{-1}) for Various Scales of Distance									
	Scales of Distance (m)									
	5000	4000	3000	2000	1000	800	600	400	200	100
$\geq$ 90	77.5	74.4	68.0	59.3	42.6	36.4	29.7	22.4	13.8	8.5
80	71.0	68.0	63.8	56.0	40.5	34.7	28.5	21.4	13.2	8.1
70	63.5	61.0	57.9	52.0	38.8	33.1	27.0	20.3	12.5	7.7
60	56.0	54.7	52.3	47.4	36.0	31.0	25.3	18.9	11.7	7.2
50	47.5	47.0	46.2	43.8	33.0	28.3	23.2	17.5	10.7	6.6
40	39.0	38.0	37.0	35.3	29.5	25.3	20.6	15.5	9.6	5.9
30	30.6	30.0	29.4	26.9	22.6	19.4	15.8	11.9	7.3	4.5
20	18.0	17.5	16.7	15.7	14.2	12.2	9.9	7.5	4.6	2.8

SECTION I. REFERENCES

I-1 Daniels, G. E. (editor), "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Space Vehicle Development," NASA TM X-53872 (Second Printing), March 15, 1970.

I-2 Brown, S. C., "Cape Kennedy Wind Component Statistics Monthly and Annual Reference Periods for All Flight Azimuths from 0 to 70 Km Altitude," NASA TM X-53956, October 9, 1969.

I-3 Smith, O. E. and G. E. Daniels, "Directional Wind Component Frequency Envelopes, Cape Kennedy, Florida, Atlantic Missile Range," NASA TM X-53009, February 21, 1964.

II. EARTH ORBITAL ENVIRONMENT

This section provides natural environment criteria for use in studies related to the NASA High Energy Astronomy Observatory (HEAO) during earth orbital phases. Values of natural environment parameters not specifically defined below will be obtained from reference II-1.

2.1 Atmospheric Gas Properties

2.1.1 Lower Thermosphere (90 to 120 km Altitude)

For nominal and extreme design values of the pressure, temperature, and density in this altitude region, the values given in paragraph 2.2.1 of reference II-1 shall be used.

2.1.2 Upper Thermosphere (120 to 1000 km Altitude)

2.1.2.1 Atmospheric Model for Orbital Altitudes

The MSFC Modified Jacchia Model Atmosphere (1967) (II-1) should be used to predict the gas properties of the atmosphere between 120 and 1000 km altitude. This model should be used with the nominal 10.7 cm solar flux and geomagnetic index values given in Table II-1 to obtain a prediction of the nominal gas properties and with the 95 percentile solar flux and geomagnetic index values to obtain an upper limit for the gas properties. The HEAO should be designed to operate successfully in the environment defined by the upper limit gas properties.

2.1.3 Structure and Variability of the Upper Atmosphere

Additional information relative to the structure and variability of the atmosphere is given in references II-2 and II-3.

2.2 Ionosphere

In HEAO studies relative to communication, telemetry, etc., the earth's ionospheric properties must be considered. The criteria that should be used in these studies are given in paragraph 2.3 of reference II-1.

2.3 Radiation

The natural radiation environment consists of galactic cosmic radiation, geomagnetically trapped radiation, and solar flare particles.

This environment may be defined by establishing a description of the particle flux as a function of energy, species, and location (time and space).

The radiation doses that might result from man-made sources, such as nuclear reactors, are not considered to be part of the natural environment and, therefore, are not included.

2.3.1 Galactic Cosmic Radiation

Criteria relative to the galactic cosmic radiation that should be used in HEAO studies are given in paragraph 2.4.1 of reference II-1.

2.3.2 Trapped Radiation

Criteria relative to the trapped radiation that should be used in the HEAO program are given in paragraph 2.4.2 of reference II-1.

2.3.3 Solar Particle Events

Solar particle events are the emission of charged particles from disturbed regions on the sun during solar flares. They are composed of energetic protons and alpha particles that occur sporadically and last for several days.

2.3.3.1 Particle Event Model

The free-space particle event model to be used in HEAO studies is given below.

$$\text{Protons} \quad N_p(>T) = \begin{cases} 7.25 \times 10^{11}\ T^{-1.2}; & 1\ \text{Mev} \leqq T \leqq 10\ \text{Mev} \\ 3.54 \times 10^{11}\ e^{-P(T)/67}; & 10\ \text{Mev} \leqq T \leqq 30\ \text{Mev} \\ 2.64 \times 10^{11}\ e^{-P(T)/73}; & T \geqq 30\ \text{Mev.} \end{cases}$$

$$\text{Alphas} \quad N_\alpha(>T) = \begin{cases} N_p\ (>T); & T < 30\ \text{Mev.} \\ 7.07 \times 10^{12}\ T^{-2.14}; & T \geqq 30\ \text{Mev.} \end{cases}$$

The terms $N_p(>T)$ and $N_\alpha(>T)$ are the integral fluxes in units of protons/cm^2 and alphas/cm^2, respectively. T is the particle's kinetic energy in units Mev and P(T) is the particle's magnetic rigidity in units mv given by

$$P(T) = \frac{1}{Ze}\sqrt{T(T + 2m_oC^2)},$$

where the quantity Ze is the magnitude of the particle's charge in units of electron charge, i.e., Ze = 1 for protons and Ze = 2 alphas. The rest mass energy for the particle is given by m_oC^2, i.e., m_oC^2 = 938 Mev for protons and 3728 Mev for alpha particles.

For synchronous orbit altitudes, the free-space solar particle event model described above should be used. For near-earth orbital altitudes, however, the free-space event model must be modified to account for the fact that the earth's magnetic field deflects some of the low-energy particles that would enter the atmosphere at low latitudes to the poles.

Solar particle events are more likely to occur at times of the solar maximum than at solar minimum. Current predictions indicated that the next two solar maximums will occur in 1980 and 1991. The solar particle event environment for the years 1983 through 1987, therefore, shall be considered to be one-tenth the magnitude of the model defined above. For the years 1977 through 1982 and 1988 through 1995, the particle environment shall be used as defined above.

2.3.3.2 Frequency of Occurrence

If a Poisson distribution is assumed the probability of seeing "x" particle events (equivalent to the one defined in paragraph 2.3.3.1) in "T" weeks is given by the following expression.

$$P(x) = \frac{(e)^{-.01T}(0.01T)^x}{x!}.$$

This expression may also be used to determine the number of particle events (nominal and plus-three-sigma) to be expected during a specific exposure period. These calculations have been made and are plotted versus exposure time in the figure given below. Exposure time may be a crew member's stay-time, an experiment's operational period, etc.

The 95.0 percent probability values given in Figure II-1 should be used for all HEAO design and operation studies.

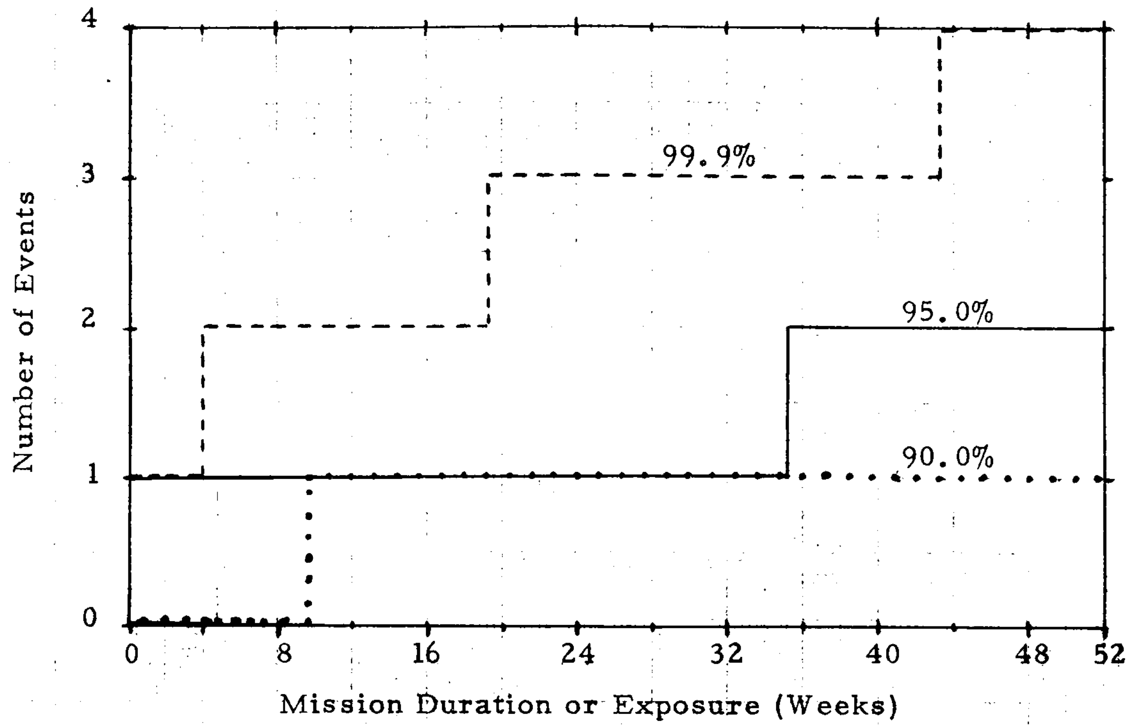

Figure II-1. Expected Number of Particle Events versus Mission Duration (90.0, 95.0, and 99.9 Percent Probabilities)

2.3.4 Thermal and Albedo Radiation

The criteria relative to the earth's thermal and albedo radiation as given in paragraph 2.4.5 of reference II-1 should be used in all HEAO studies.

2.3.5 Radiation Properties of the Sun (Thermal)

The criteria relative to the radiation properties of the sun as given in paragraph 1.3.3 of reference II-1 should be used in all HEAO studies.

2.4 Meteoroid Environment

The meteoroid environment given in paragraph 2.5 of reference II-1 shall be used for HEAO studies.

The HEAO structural design shall provide for a probability of 0.90 of no meteoroid penetration of valuable subsystems for two years after insertion into orbit.

2.5 Geomagnetic Environment

The geomagnetic environment given in paragraph 2.6 of reference II-1 should be used for all HEAO studies.

2.6 Solar Cycle Predictions

Current analyses have shown that properties of the natural atmospheric environment are dependent upon solar activity. A mathematical description of the sunspot prediction program currently in use at Marshall Space Flight Center is given in reference II-1.

An updated prediction of future solar activity parameters is issued each month by MSFC. Table II-1 contains an example of such a prediction based on the data available in December 1970. To insure that the most current data are used in HEAO studies, copies of the most recent update will be provided upon request to MSFC, Aero-Astrodynamics Laboratory, Aerospace Environment Division (S&E-AERO-YS).

2.7 Astrodynamic Constants

The astrodynamic constants given in paragraph 2.7 of reference II-1 should be used for all HEAO studies. This paragraph also provides criteria relative to the earth's gravitational potential.

TABLE II-1. Prediction of Sunspot Numbers, Solar Flux and Geomagnetic Index (Using Data Available in December 1970).

	* *SUNSPOT NUMBER* * * *		* * * 10.7 CM SOLAR FLUX * * *		* * GEOMAGNETIC INDEX KP * *	
TIME	NOMINAL	PERCENTILE 95.	NOMINAL	PERCENTILE 95.	NOMINAL	PERCENTILE 95.
1970.500	97.92	103.91	144.68	150.48	2.80	3.54
1970.750	90.53	101.21	137.54	147.87	2.80	3.54
1971.000	80.72	95.84	128.06	142.68	2.20	3.54
1971.250	71.22	87.70	118.87	134.80	2.20	3.54
1971.500	64.20	80.71	112.97	128.05	2.20	3.54
1971.750	57.89	75.43	107.76	122.94	2.20	3.02
1972.000	53.98	73.99	104.54	121.55	2.20	3.02
1972.250	51.04	71.45	102.10	119.09	2.20	3.02
1972.500	46.05	65.57	97.99	114.09	2.20	3.02
1972.750	41.27	63.02	94.05	111.99	2.20	3.02
1973.000	37.16	59.13	90.66	108.79	2.20	3.02
1973.250	32.86	56.03	87.11	106.22	2.20	3.02
1973.500	29.82	53.38	85.89	104.04	2.20	3.02
1973.750	27.11	49.15	84.26	100.55	2.20	3.02
1974.000	24.10	44.04	82.46	96.33	2.20	3.02
1974.250	21.70	39.79	81.02	92.83	2.20	3.02
1974.500	20.13	37.68	80.08	91.09	2.20	3.02
1974.750	17.63	34.15	78.58	88.17	1.80	3.02
1975.000	16.11	32.04	77.67	86.43	1.80	3.02
1975.250	16.94	35.92	78.17	89.63	1.80	3.02
1975.500	18.18	44.28	78.91	96.53	1.80	3.02
1975.750	21.87	58.38	81.12	108.16	2.20	3.02
1976.000	27.22	75.61	84.33	123.11	2.20	3.54
1976.250	32.89	89.44	87.13	136.49	2.20	3.54
1976.500	41.08	106.24	93.89	152.74	2.20	3.54
1976.750	49.61	121.27	100.92	167.27	2.20	3.54
1977.000	58.21	132.73	108.02	178.35	2.20	3.54
1977.250	67.82	144.98	115.95	190.20	2.20	3.54
1977.500	73.26	151.44	120.84	196.44	2.20	3.54
1977.750	79.07	156.63	126.46	201.47	2.20	3.54
1978.000	86.45	167.38	133.60	211.86	2.80	3.54
1978.250	91.88	176.50	138.85	220.68	2.80	3.54
1978.500	97.35	182.72	144.14	226.69	2.80	3.54
1978.750	100.33	184.08	147.02	228.01	2.80	3.54
1979.000	101.39	182.49	148.04	226.47	2.80	3.54
1979.250	101.61	179.14	148.26	223.23	2.80	3.54
1979.500	101.97	175.11	148.60	219.33	2.80	3.54
1979.750	101.05	172.16	147.72	216.48	2.80	3.54
1980.000	97.26	160.94	144.06	205.63	2.80	3.54

SECTION II. REFERENCES

II-1 Weidner, D. K. (editor), "Space Environment Criteria Guidelines for Use in Space Vehicle Development (1969 Revision)," NASA TM X-53957 (second edition), August 26, 1970.

II-2 NASA SP-8021, "Models of Earth's Atmosphere (120 to 1000 km)," May 1969.

II-3 Weidner, D. K., G. S. West, and G. R. Swenson, "Variations in Orbital Altitude Atmospheric Density for MSFC 1971-1976 Space Station Programs," NASA TM X-53815, February 1969.

APPROVAL

NATURAL ENVIRONMENT CRITERIA FOR THE
NASA HIGH ENERGY ASTRONOMY OBSERVATORY (HEAO)

by Don K. Weidner and George S. West

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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