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

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16. ABSTRACT

This document provides environment criteria for the NASA High Energy Astronomy Observatory (HEAO) Program. Information in selected disciplinary areas is given for the region of space that is within 1000 km from the earth's surface. This report supersedes NASA TMX-64576, "Natural Environment Criteria Guidelines for the HEAO," dated March 25, 1971.

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SECTION I. SUMMARY

This document provides natural environment criteria for the NASA High Energy Astronomy Observatory (HEAO) Program. 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, other NASA Centers, and government agencies.

SECTION II. INTRODUCTION

The natural environment and physical standards to be used for the NASA HEAO studies are included in this document. Two supporting documents have been published: "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development (1973 Revision)," TM X-64757, July 5, 1973, and "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development (1971 Revision)," NASA TM X-64627, November 15, 1971, plus addenda to these documents.

For those HEAO's to be flown on the Space Shuttle, the natural environments given in the Space Shuttle Program Level II Program Definition and Requirements Document should be used (III.4).

Natural environment conditions encountered by spacecraft and launch vehicles are important factors in studies relative to design, preflight 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.

SECTION III. PRELAUNCH, 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 HEAO Program during prelaunch, launch, and inflight phases. Values of natural environment parameters not specifically defined below may be obtained from material given in References III-1 and III-2.

A. Gas Properties

1. Nominal Gas Properties. The Cape Kennedy Reference Atmosphere (CKRA) given in Table 14.12 of Reference III-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".

2. Extreme Gas Properties. For problems requiring extremes of pressure, temperature, and density versus altitude, the coefficients of variation (CV) from Table 14.9 of Reference III-1 and the mean values from Table 14.12 of Reference III-1 should be applied as follows:

$$\text{Maximum Parameter} = \text{CKRA} \left[1 + \frac{3\,\text{CV}}{100}\right] \qquad (1)$$

$$\text{Minimum Parameter} = \text{CKRA} \left[1 - \frac{3\,\text{CV}}{100}\right] \quad . \qquad (2)$$

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 (paragraph 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.

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 14.10 of Reference III-1 should be used.

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 14.9 of Reference III-1 and the mean atmospheric values from Table 14.12 of Reference III-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

5. Standard Day. For purposes of engine ratings and comparisons thereof, the sea-level values of temperature, pressure, and density as given by the U. S. Standard Atmosphere 1962 shall be used. See Section 14.1 of Reference III-1.

B. Winds

For launch and onpad 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 exceeding the expected operational modes may then be determined.

1. Ground Winds. To provide a reasonable launch and onpad stay-time capability for the HEAO plus launch vehicle, the following ground wind speed values from any azimuth should be used. For launch, the five percent risk for the windiest hour exposure period as given in Table 5.2.2 of Reference III-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 onpad exposure time of the HEAO as given in Table 5.2.5 of Reference III-1 should be used. This peak wind speed profile shall be used to calculate vehicle onpad base overturning moments and vortex shedding loads. Calculations to establish the launch vehicle plus HEAO ground wind contraints, 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 III-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.

2. Inflight Winds.

a. Rigid body studies. The HEAO launch vehicle inflight wind analysis should be conducted with respect to the 95-percentile directional wind speed envelopes as given in Table III-1. These wind speed envelopes were extracted from Reference III-3. It should be noted that the directional wind speed envelopes in Table III-1 are valid for a narrow range of flight azimuths ($\pm 10°$) about the indicated flight azimuths. If directional wind speed envelopes are required for other flight azimuths, they can be made available upon request to the Chief of the Aerospace Environment Division (S&E-AERO-Y), MSFC. 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 III-2 and III-3.

For calculations 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 III-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 (Section 5.3.8, Reference III-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.

TABLE III-1. DIRECTIONAL STEADY-STATE WIND SPEED PROFILE ENVELOPES FOR SELECTED FLIGHT AZIMUTHS, CAPE KENNEDY, FLORIDA.*

50°H		50°T		50°RC		50°LC		90°H		90°T		90°RC		90°LC	
A	W_s	A	W_s	A	W_s	A	W_s	A	W_s	A	W_s	A	W_s	A	W_s
1	12	1	15	1	11	1	13	1	12	1	16	1	13	1	10
4	9	11	63	4	7	7	32	4	9	4	30	3	14	5	12
10	14	12	64	9	8	11	52	9	11	9	60	5	18	10	22
13	22	13	62	13	12	12	53	13	19	11	70	6	19	13	28
14	21	20	17	16	8	13	50	17	12	12	72	11	28	19	8
17	12	23	16	17	8	20	15	18	13	13	70	12	28	20	8
20	15	50	95	20	15	22	12	20	19	20	20	13	27	23	8
50	47	54	96	23	15	40	57	23	19	23	20	19	9	50	30
60	52	60	95	50	60	50	74	50	72	50	120	20	8	60	30
75	30	75	70	60	62	60	74	60	72	60	120	23	8	75	20
80	30	80	70	75	29	75	44	75	50	75	90	50	52	80	20
				80	29	80	44	80	50	80	90	60	52		
												75	30		
												80	30		

108°H		108°T		108°RC		108°LC	
A	W_s	A	W_s	A	W_s	A	W_s
1	11	1	15	1	14	1	11
3	9	11	65	3	17	2	9
8	9	12	67	11	42	6	11
13	17	13	64	12	42	11	21
17	11	20	19	13	40	13	23
20	19	23	19	20	11	19	9
23	19	40	75	23	11		
26	26	47	80	42	39		
35	36	50	90	47	58	33	12
47	61	57	100	50	60	41	19
50	65	60	100	60	60	50	20
60	72	75	50	75	40	58	26
75	30	80	50	80	40	60	32
80	30					75	21
						80	21

A = Altitude - km
W_s = Wind Speed - ms^{-1}
H = Head Wind
T = Tail Wind
RC = Right Crosswind
LC = Left Crosswind

* Wind profiles are obtained by linear interpolation between indicated values above the 1-km level.

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 one percent risk gust and shear combination rather than the separate addition of the one percent risk values for the gusts and shears in a perfectly correlated manner. It is recommended that a series of synthetic wind speed profiles be constructed, with each profile having a different reference point at which the design shear envelope intersects the design wind speed profile envelope. Loads should be calculated for each profile, and the design-synthetic wind speed profile will be determined by

TABLE III - 2. IDEALIZED ENVELOPES OF 99 PERCENTILE SCALAR BUILDUP 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
≥ 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 III - 3. IDEALIZED ENVELOPES OF 99 PERCENTILE SCALAR BACKOFF 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
≥ 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

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 III-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.

b. 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 (cycles/meter). 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. This wind shear/spectrum combination will result in a one percent risk of encountering the design shear/spectrum combination, given that the HEAO is launched into the design steady-state wind condition.

C. 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 III-1. If additional criteria, e.g., 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.

REFERENCES

III-1. Daniels, G. E. (editor): Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, NASA TM X-64757, July 5, 1973.

III-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.

III-3. Falls, L. W.: Normal Probabilities for Cape Kennedy Wind Components - Monthly Reference Periods for All Flight Azimuths - Altitude 0-70 Kilometers, NASA TM X-64770, April 16, 1973.

III-4. Appendix 10.10, Natural Environment Design Requirement, Space Shuttle Program Level II Program Definition and Requirements, vol. X, Document no. JSC 07700.

SECTION IV. TERRESTRIAL SPACE AND 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 IV-1.

A. Definition

"Terrestrial space" is defined in this document as the region between 90 and 65 000 km above the surface of the earth for all environment components except meteoroids, where the outer limit of the earth's sphere of influence extends into space until the gravitational attraction becomes negligible.

B. Neutral Gas Properties[1]

Atmospheric conditions encountered by a spacecraft in orbit about the earth are important factors in space vehicle design, mission planning, and mission operations. Density is the primary atmospheric property that affects the spacecraft's orbital altitude, lifetime, and motion in the altitude range of 90 to 1000 km. Near the lower limit of this range where density is greatest, a spacecraft will generally remain in orbit for a very short time; near the upper limit, the density effect on orbital lifetime is almost negligible. Density directly affects the torques which result from aerodynamic interaction between the space vehicle and the atmosphere; such torques must be considered in design of spacecraft attitude control systems. Density scale height is required in heating calculations for space vehicles reentering the earth's upper atmosphere. Density, as well as chemical composition and temperature, is needed in calculating a spacecraft's drag coefficient. Chemical composition and temperature are also required in the design of experiment sensors to be flown in this altitude range.

Because of variability of atmospheric conditions with spatial location and solar condition, invariant models of the earth's atmosphere (90 to 2500 km) are not useful for most engineering applications. Therefore, a computerized version of a prediction method to provide models of the earth's atmosphere which vary with solar condition and location is required. The resulting atmospheric models, which are predicted for particular times and locations,

1. Appendix B of NASA TM X-64627 contains a complete discussion.

provide atmospheric density, chemical composition, temperature, molecular mass, and density scale height between 90 and 2500 km altitude.

Most of the density values for the atmosphere between 90 and 2500 km have been derived from the analysis of changes in the periods of orbiting satellites. Temperature and chemical composition may be inferred from the drag determined densities under the assumption of static diffusion. Since mass density, temperature, and chemical composition at these altitudes vary with solar and geomagnetic activity, the level of such activity must be considered to estimate these parameters for a given time.

1. Variations.

a. Chemical Composition. In the earth's homosphere, extending from the surface to an altitude of near 90 to 100 km, the atmospheric gases mix thoroughly so the constituent gas distribution (chemical composition) does not vary. However, above 90 km and primarily near 105 km, extreme ultraviolet (EUV) solar radiation causes molecular oxygen to dissociate. The resulting atomic oxygen is then transported up and down, changing constituent distribution. Accordingly, the chemical composition above the 90- to 100-km altitude level is a function of the variable amounts of EUV radiation received from the sun.

b. Temperature. The temperature lapse rate is influenced by solar radiation. In the lower thermosphere (100 to 300 km), solar radiation in the EUV band (40 to 1000Å) is absorbed and causes the temperature to increase steadily with altitude. Above 300 km, where little or no solar radiation is absorbed, the temperature increases very little with altitude and becomes isothermal as shown in Figure IV-1. The isothermal temperature, which is designated as the "exospheric temperature", varies diurnally, seasonally, and with solar and geomagnetic activity from about 650° to 2100°K.

c. Density. Variation in density has been found to be related closely to the amount of EUV received from the sun. Although EUV cannot be measured at the earth's surface, early investigators assumed that there was correlation between EUV and radiation at about 10-cm wavelength which can be measured at the earth's surface. Data from the first Orbiting Solar Observatory (OSO-1) confirmed this assumption, showing close correlation between EUV and radiation at 10.7 cm [IV-1]. Therefore, the mean daily solar flux at 10.7 cm which is measured by the National Research Council, Ottawa, Canada, has been accepted as an indicator of the amount of EUV radiation that reaches the atmosphere.

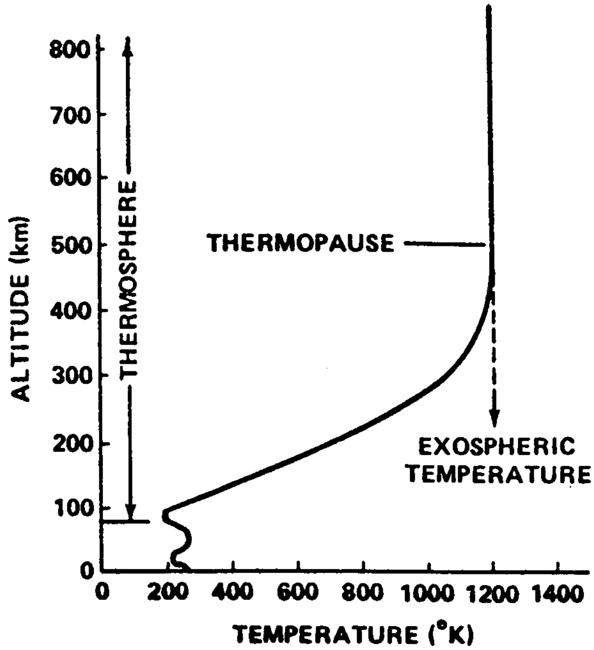

Figure IV-1. Typical plot of temperature versus altitude and exospheric temperature.

The principal periodic variability found in the solar flux at 10.7 cm occurs at a cycle of 27 days, corresponding to the 27-day solar rotation. The same periodicity is reflected in atmospheric density. Semiannual, diurnal, and 11-year or solar cycle variations have also been identified (Fig. IV-2).

Density variation also can be related to fluctuations in the three-hourly geomagnetic index of magnetic activity at the earth's surface. Although the physical relationship between geomagnetic activity and density variation is not known, the correlation between changes in geomagnetic activity and density variation is useful in density prediction.

Density also varies between the winter and summer hemispheres in the 60- to 80-deg latitude range. Some investigators attribute the higher density in the winter hemisphere to increased concentration of helium.

d. Criteria. The upper atmosphere model used by MSFC is described in Appendix B of NASA TM X-64627 and should be used to predict the neutral gas properties of the atmosphere between 90 and 2500 km altitude for orbital dynamics, lifetime, and control guidance analyses. The model should be used for reentry and analyses from orbital altitudes down to 25 km above the earth's surface. This model provides only nominal atmospheric density data below 90 km. Solar activity data required for input to this model are described in Section 2.4.7 and Appendix A of NASA TM X-64627.

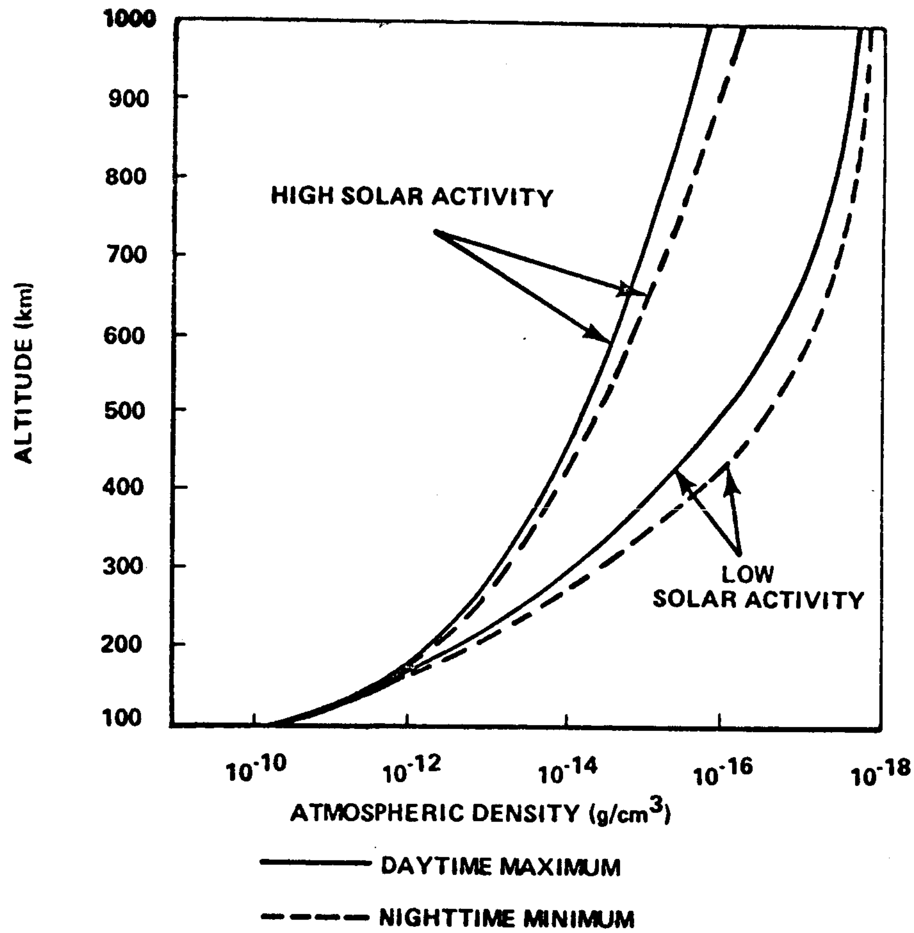

Figure IV-2. Typical daytime maximum and nighttime minimum atmospheric density profiles for high and low solar activity.

2. 2500- to 65 000-km Altitude. Gas pressure decreases exponentially with increasing altitude above 2500 km until it reaches the interplanetary value of 10^{-10} dynes/cm^2 near 20 000 km. It then remains relatively constant with increasing altitude.

Gas density decreases exponentially above 2500 km altitude to a value of 10^{-23} g/cm^3 near 20 000 km and then remains relatively constant to 65 000 km altitude.

Kinetic temperature increases linearly above 2500 km to about 2×10^5°K at 20 000 km and then remains relatively constant with increasing altitude.

3. Additional Information. Additional information relative to the structure and variability of the atmosphere is given in References IV-1 and IV-2.

C. 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 IV-1.

D. 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.

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 IV-1.

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 IV-1.

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.

a. 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 $N_p\ (> T)_2$ 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

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

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 $m_o C^2$; i.e., $m_o C^2 = 938$ 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.

b. Frequency of occurrence. If a Poisson distribution is assumed the probability of seeing "x" particle events in "T" weeks is given by the following expression.

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

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, and so forth.

The 95.0 percent probability values given in Figure IV-3 should be used for all HEAO design and operation studies.

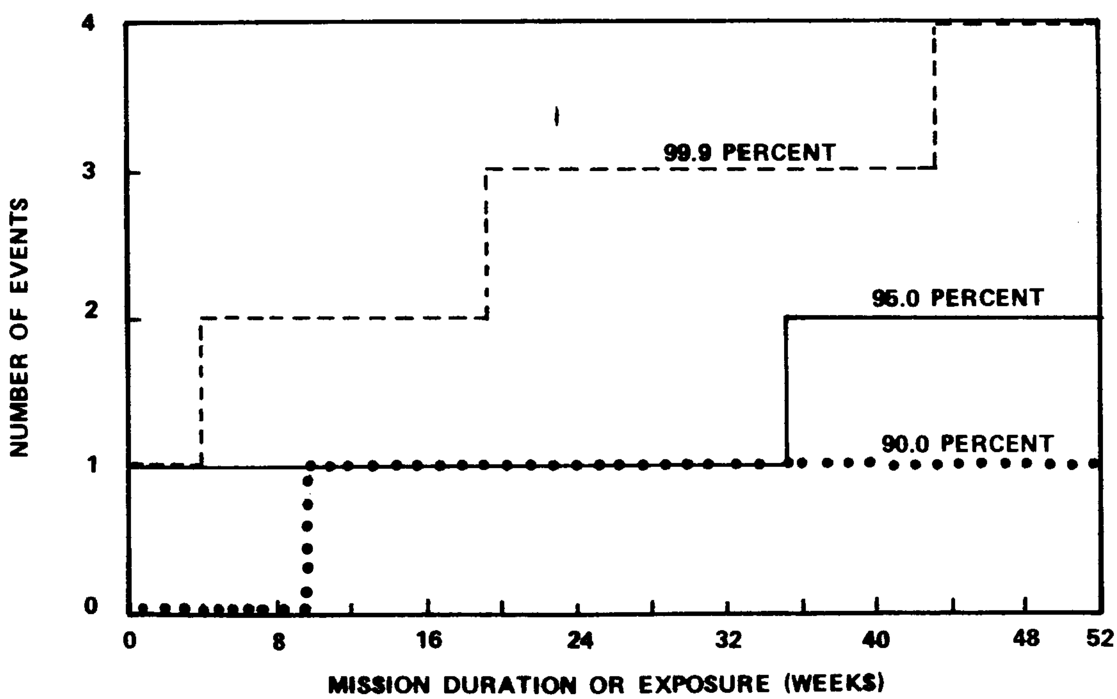

Figure IV-3. Expected number of particle events versus mission duration (90.0, 95.0, and 99.9 percent probabilities).

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 IV-1 should be used in all HEAO studies.

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 IV-1 should be used in all HEAO studies.

E. Meteoroid Environment

The meteoroid environment given in paragraph 2.5 of Reference IV-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.

F. Geomagnetic Environment

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

G. 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 IV-1.

An updated prediction of future solar activity parameters is issued each month by MSFC. Table IV-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).

H. Astrodynamic Constants

The astrodynamic constants given in paragraphs 1.6 and 2.7 of Reference IV-1 should be used for all HEAO studies. These paragraphs also provide criteria relative to the earth's gravitational potential.

TABLE IV-1. EXAMPLE 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 95.0	Nominal	Percentile 95.0	Nominal	Percentile 95.0
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	211.88	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	228.47	2.80	3.54
1979.250	101.61	179.14	148.26	223.23	2.80	3.54
1979.500	101.97	175.11	148.80	219.33	2.80	3.54
1979.750	101.05	172.16	147.78	216.40	2.80	3.54
1980.000	97.26	160.94	144.06	205.83	2.80	3.54

* See Paragraph G , Section IV.

REFERENCES

IV-1. Smith, R. E., (editor), "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development (1971 Revision)," NASA TM X-64627, November 15, 1971.

IV-2. NASA SP-8021, "Models of Earth's Atmosphere (90 to 2500 km)," (1973 Revision), Dated March, 1973.

APPROVAL

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

By Lewis E. Andrews

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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