NASA Technical Memorandum

NASA TM- 86498

NATURAL ENVIRONMENT DESIGN CRITERIA FOR THE SPACE STATION DEFINITION AND PRELIMINARY DESIGN (SECOND REVISION)

By William W. Vaughan and Claude E. Green

Atmospheric Sciences Division
Systems Dynamics Laboratory

March 1985

(NASA-TM-86498) NATURAL ENVIRONMENT DESIGN CRITERIA FOR THE SPACE STATION DEFINITION AND PRELIMINARY DESIGN (NASA) 16 p HC A02/MF A01 CSCL 22B

N85-21232

Unclas
G3/15 14545

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM- 86498	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Natural Environment Design Criteria for the Space Station Definition and Preliminary Design (Second Revision)		5. REPORT DATE March 1985
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) William W. Vaughan and Claude E. Green		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Atmospheric Sciences Division, Systems Dynamics Laboratory.

16. ABSTRACT

This document provides the natural environment design criteria for the Space Station Program (SSP) definition and preliminary design. It addresses the atmospheric dynamic and thermodynamic environments, meteoroids, radiation, magnetic fields, physical constants, etc., and is intended to enable all groups involved in the definition and preliminary design studies to proceed with a common and consistent set of natural environment criteria requirements. The Space Station Program Elements (SSPE) shall be designed with no operational sensitivity to natural environment conditions during assembly, checkout, stowage, launch, and orbital operations to the maximum degree practical.

NOTE: This report supersedes NASA TM-86460 "Natural Environment Design Criteria for the Space Station Definition and Preliminary Design (First Revision)" Dated September 1984

17. KEY WORDS Space Station, Natural Environment, Atmospheric Density, Radiation, Meteoroids, Design Criteria	18. DISTRIBUTION STATEMENT Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassifed	Unclassified	15	NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

TECHNICAL MEMORANDUM

NATURAL ENVIRONMENT DESIGN CRITERIA FOR THE SPACE STATION DEFINITION AND PRELIMINARY DESIGN (SECOND REVISION)

1.0 PURPOSE AND SCOPE

This document is to define the natural environment design criteria for the SSP and its elements (SSPE). It will be reviewed and updated, where warranted, for the SSPE Definition and Preliminary Design System Requirements Review (SRR).

2.0 GENERAL

The natural environment criteria given herein will be used in the design of the Space Station Program Elements (SSPE). Where the natural environment design requirements are schedule, time, and orbit dependent, the SSPE are based on an Initial Operational Capability (IOC) in the early 1990's with an indefinite design lifetime. For those natural environment parameters which require a specific SSPE reference lifetime, a minimum of 10 years will be used for design trade studies. Design value requirements of natural environment parameters not specifically defined in this document will be obtained from NASA TM 82473, "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development," 1982 Revision, and NASA TM 82478, "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development," 1982 Revision (Volume I). The SSPE shall be designed with no operational sensitivity to natural environment conditions during assembly, checkout, stowage, launch, and orbital operations to the maximum degree practical. Natural environmental data required for definition and preliminary design studies which are not contained in the above documents or detailed herein shall be obtained from, or be approved by, the Chief, Atmospheric Sciences Division (ED41), MSFC. These requests should be made through the cognizant NASA Program Office representative. These additional requirements will be reflected in the next update of this document.

SSPE operating within the orbital parameters established for Space Station will be affected by the following:

Environmental Factors	Effect
Earth's gravity	Acceleration, torque
Neutral atmosphere	Heating and drag, torque
Sunlight and albedo light	Heating and power, drag, torque
Magnetic field	Torque, surface changes, induced electrical potential
Electrical field	Electrical potential
Thermal plasma	Charging, change of refractive index for em waves
Fast charged particles	Ionization, radiation damage
Meteoroids	Mechanical damage

The SSPE design should be assessed against the most severe combination of natural environments derived from the above references or contained herein for operation within the orbital design range given in Table 1.

TABLE 1. SPACE STATION PROGRAM ELEMENTS (SSPE) ORBITAL PARAMETERS

	Nominal		Design Altitude Range	
Element	Altitude	Inclination (degrees)	High	Low
Space Station	500 km (270 n.mi.)	28.5	555 km (300 n.mi.)	463 km (250 n.mi.)
Co-Orbiting Platform(s)	500 km (270 n.mi.)	28.5	1000 km (540 n.mi.)	463 km (250 n.mi.)
Polar Platform(s)[a]	705 km (381 n.mi.)	98.25[b]	900 km (486 n.mi.)	400 km (216 n.mi.)

a. Polar servicing altitude 276 km (149 n.mi.)

b. Inclination is a slightly varying function of altitude for sunsynchronous orbit.

3.0 NEUTRAL ATMOSPHERE ON-ORBIT

The MSFC/J70 Reference Orbital Atmosphere Model (section A.3, appendix A, of NASA TM 82478) will be used to calculate ambient gas constituents, i.e., atomic oxygen, etc., number densities and total density of the orbital altitude atmosphere for SSPE's design requirements. Inputs required for the model calculations will be provided upon request. Table 1 provides the SSPE orbital characteristics extracted from the September 14, 1984, "Space Station Definition and Preliminary Design Request for Proposal."

3.1 Guidance and Control System (Low Inclination Orbit)

The design mean value of total density over an orbit to be used for control stability requirements determination is given in Table 2.

3.2 Guidance and Control System (Polar Orbit)

The design mean value of total density over a polar orbit to be used for control stability requirements determination is given in Table 3.

These values do not account for the within-orbit atmospheric density or geomagnetic storm variations. These design requirements are currently being developed and estimates are available upon request.

3.3 Reboost and Orbit Maintenance (Low Inclination Orbit)

The design steady-state values of total density to be used for Space Station design reboost and orbit maintenance requirements analyses are given in Figure 1,

TABLE 2. DESIGN G&C SYSTEM MEAN TOTAL DENSITY FOR A LOW INCLINATION ORBIT

Orbital Altitude	Total Density (kg/m^3)
1100 km (594 n.mi.)	0.5189×10^{-13}
1000 km (540 n.mi.)	0.1018×10^{-12}
900 km (486 n.mi.)	0.2105×10^{-12}
800 km (432 n.mi.)	0.4567×10^{-12}
700 km (378 n.mi.)	0.1042×10^{-11}
600 km (324 n.mi.)	0.2522×10^{-11}
555 km (300 n.mi.)	0.3814×10^{-11}
500 km (270 n.mi.)	0.6596×10^{-11}
463 km (250 n.mi.)	0.9693×10^{-11}
400 km (216 n.mi.)	0.1958×10^{-10}

Ref $\bar{F}_{10.7}(230)$ $A_p(400)$

TABLE 3. DESIGN G&C SYSTEM MEAN TOTAL DENSITY FOR A POLAR ORBIT

Orbital Altitude	Total Density (kg/m^3)
1000 km (540 n.mi.)	0.9890×10^{-13}
900 km (486 n.mi.)	0.2055×10^{-12}
800 km (432 n.mi.)	0.4483×10^{-12}
750 km (405 n.mi.)	0.6743×10^{-12}
705 km (380 n.mi.)	0.9846×10^{-12}
600 km (324 n.mi.)	0.2498×10^{-11}
500 km (270 n.mi.)	0.6579×10^{-11}
400 km (216 n.mi.)	0.1953×10^{-10}
300 km (162 n.mi.)	0.7096×10^{-10}

Ref $\bar{F}_{10.7}(230)$ $A_p(400)$

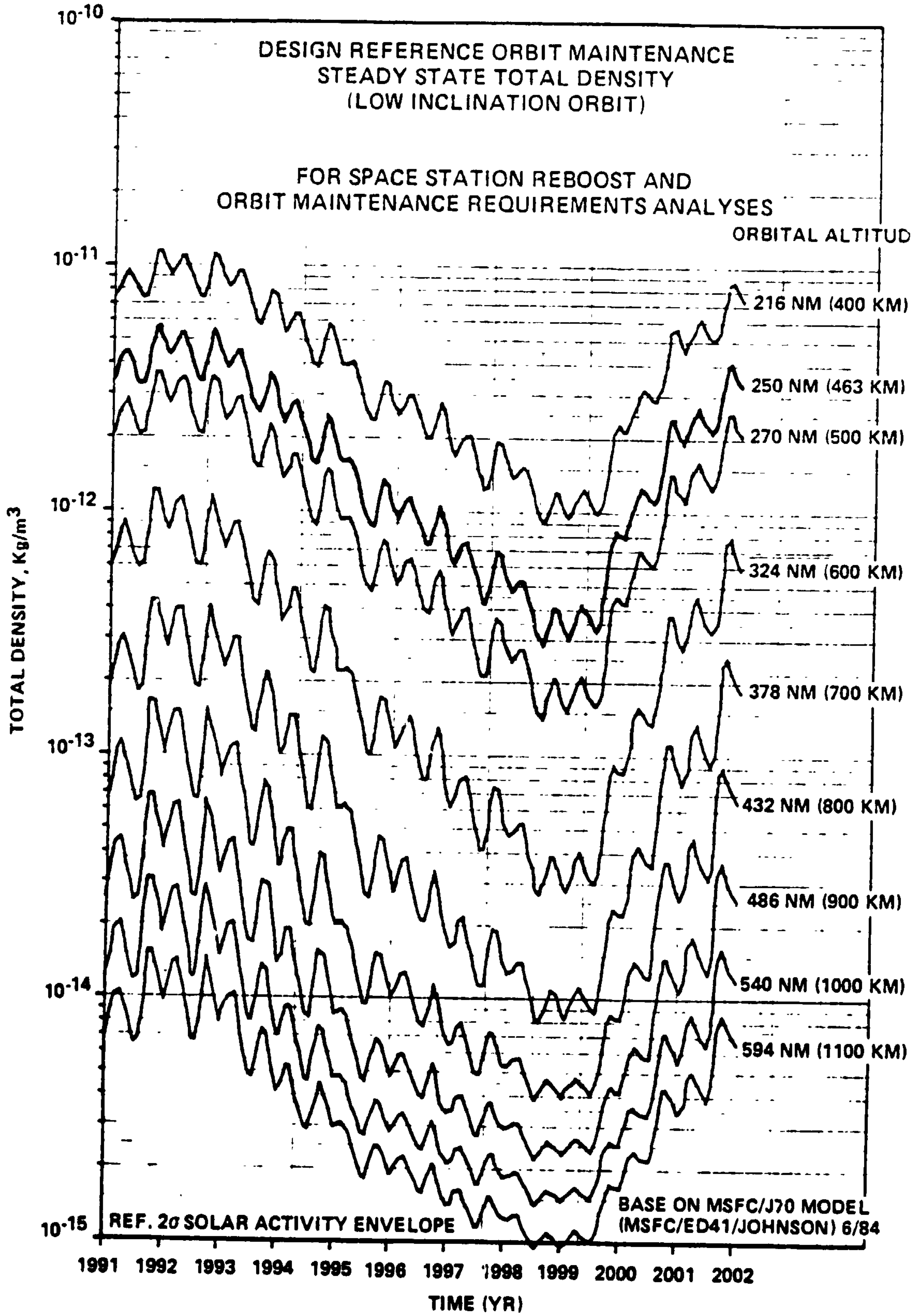


Figure 1. Design reference orbit maintenance steady-state total density (low inclination orbit).

Design Reference Orbit Maintenance Steady-State Total Density. (These design values will be updated within two years after minimum of current solar cycle.) These steady-state density values do not account for the within-orbit density dynamics or geomagnetic storm variations. They represent average values of density over the globe. Estimates on the variations are available if required for specific analyses.

3.4 Reboost and Orbit Maintenance (Polar Orbit)

The design steady-state values of total density to be used for Space Station design reboost and orbit maintenance requirements analyses are given in Figure 2, Design Reference Steady-State Orbit Maintenance Total Density (Polar Orbit). (These design values will be updated within two years after minimum of current solar cycle.) These steady-state density values do not account for the within-orbit density dynamics or geomagnetic storm variations. They represent average values of density over the polar orbital range of latitudes. Estimates on the variations are available if required for specific analyses.

3.5 End of Life Entry Analyses

The MSFC Global Reference Atmosphere Model (GRAM) (section 3.8.1 of NASA TM 82473) will be used for end of life disposal concept assessments relative to heating, breakup, and dispersion. The appropriate input parameters for the model depend upon date(s) assumed for end of life estimate and are available upon request.

3.6 Contamination

The design values for on-orbit ambient atmosphere constituents number densities that should be assessed relative to potential contribution to contamination due to atomic oxygen, etc., gas properties are given in Figure 3, Constituent Number Density. Further details on short-term dynamics of constituent number densities for geomagnetic storms are available if required.

4.0 SPACECRAFT CHARGING

The SSPE's electronic systems and surface structures will be designed to minimize the effects of spacecraft charging due to the buildup of large differential potentials. (See section 2.9 of NASA TM 82478.)

5.0 RADIATION

The SSPE's habitability and electronic systems/modules will be designed to minimize the effects of charged particle radiation, plasma and electromagnetic fields. In addition to the following requirements, section 2.7 (Plasma and Electromagnetic Fields) and section 2.8 (Charged Particles) of NASA TM 82478 will be used to develop necessary protection to ensure that the safe dosage limits of the equipment and crew are not exceeded over the lifetime of the SSPE's.

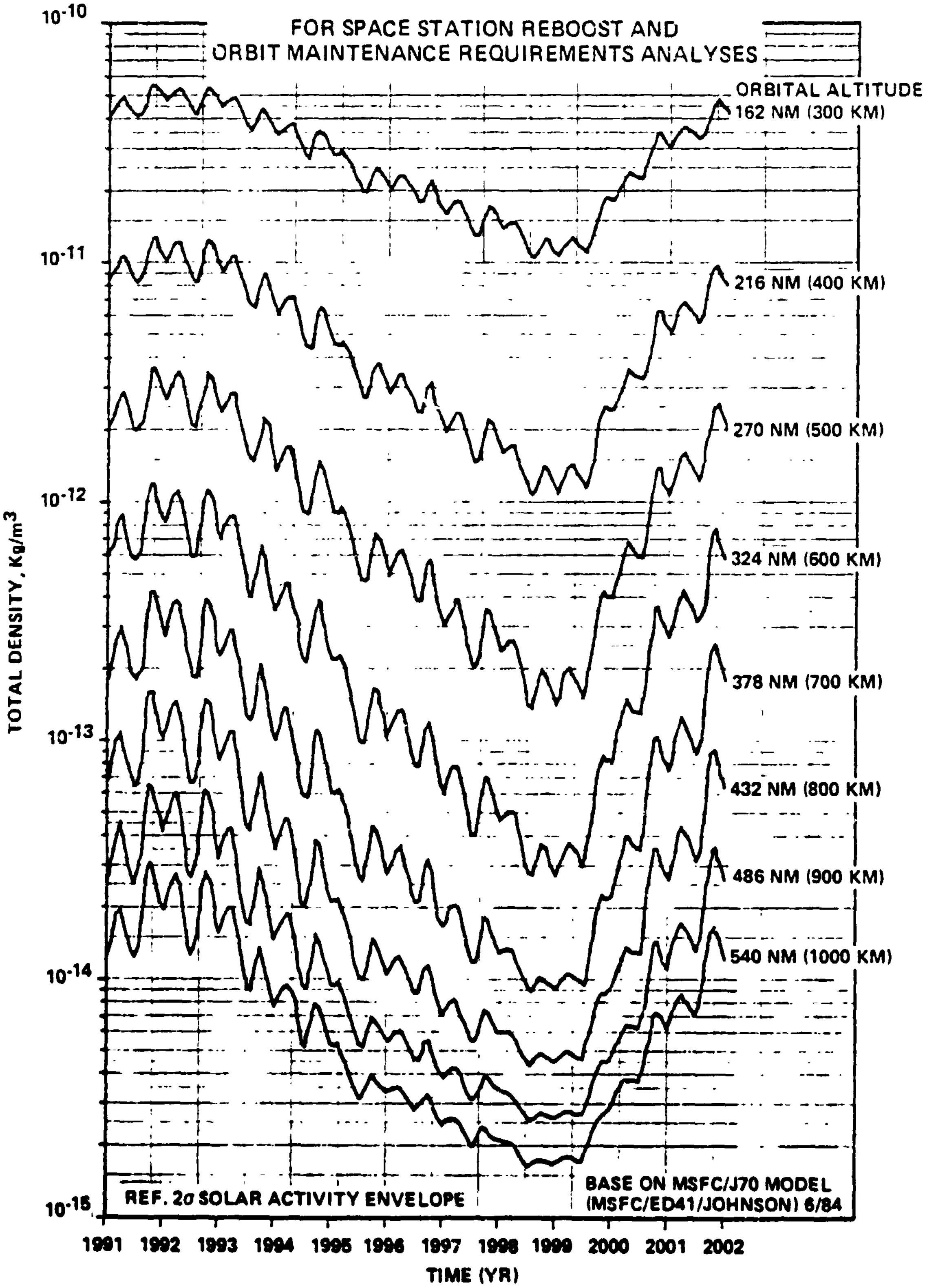
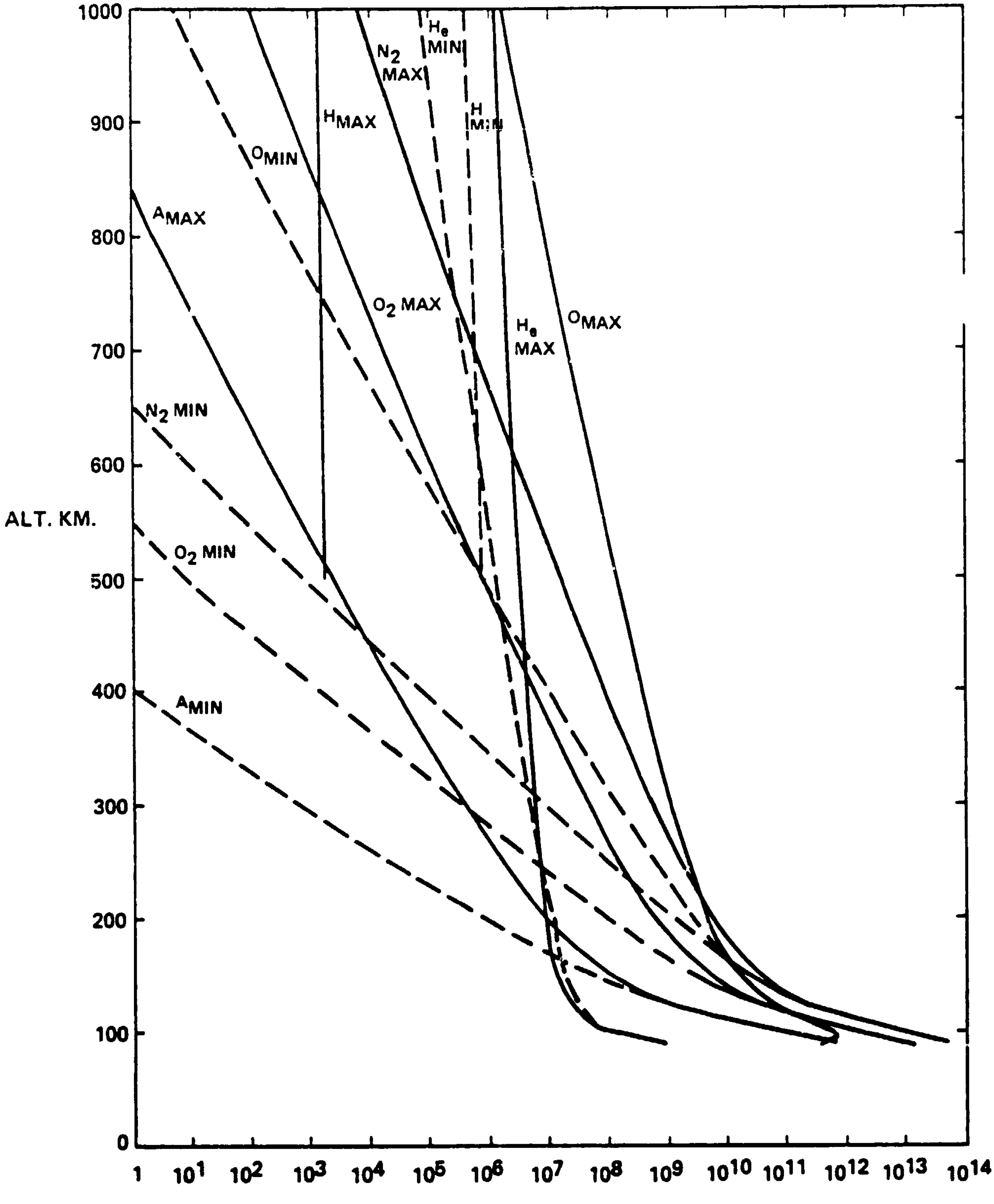


Figure 2. Design reference orbit maintenance steady-state total density (polar orbit).



USING MSFC–J70–3

FOR: MIN SOLAR CONDITIONS: 0400 hrs. USING $F_{10.7}$ = 70 & Ap = 0

MAX SOLAR CONDITIONS: 1400 hrs. USING $F_{10.7}$ = 230 & Ap = 35

Figure 3. Constituent number density.

5.1 Cosmic Radiation

There are two types of cosmic radiation: galactic and solar. Galactic cosmic rays are those which have a steady stream flux intensity from outside the solar system. They are highest during periods of solar activity minimum and have energies up to 10^{20} eV. (See Section 2.8.4 of NASA TM 82478.)

Solar cosmic rays come in bursts from the sun in solar flare events. A stream of solar cosmic rays reaches and envelops the Earth within minutes after a solar flare event; it reaches peak intensity in a few hours and then decays in 1 to 2 days. These rays are generally of lower energy than galactic cosmic rays. (See section 2.8.5 of NASA TM 82478.) Design estimates of the daily cosmic ray dose for the various orbits can be calculated using procedures found in "Estimation of Galactic Cosmic Ray Penetration and Dose Rates," NASA TN-D6600 by M. O. Burrell and J. J. Wright, dated March 1972.

5.2 Trapped Radiation

5.2.1 Near Earth orbit environment

The radiation belts trapped near the Earth are approximately azimuthally symmetric, with the exception of the South Atlantic anomaly where the radiation belts reach their lowest altitude. The naturally occurring trapped radiation environments in the anomaly region remain fairly constant with time although they do fluctuate with solar activity. Electrons will be encountered at low altitudes in the anomaly region as well as in the auroral zones.

The trapped radiation environment will be calculated using the TRECO computer code (National Space Science Data Center, NASA-Goddard Space Flight Center) and merged with trajectory information to find particle fluxes and spectra for design. The fluxes and spectra will be converted to dose by algorithms and/or computer codes provided upon request to the Director, Space and Life Science Directorate (SA), JSC.

5.2.2 Geosynchronous orbit environment

The trapped proton environment at synchronous orbit altitude is of no direct biological significance but may cause deterioration of material surfaces over long exposure time. The proton flux at this altitude is composed of only low energy protons (less than 4 MeV) and is on the order of 10^5 protons/cm^2-sec. The trapped electron environment at synchronous altitude is characterized by variations in particle intensity of several orders of magnitude over periods as short as a few years. See section 2.4.2 of NASA TM 82478.

5.3 High Energy Solar Particle Event

High energy solar particle events are the emission of charged particles from disturbed regions of the Sun during large solar flares. They are composed of energetic protons and alpha particles. Although they are relatively infrequent (34 events during solar cycle 19, and 20 events during solar cycle 20 with particle energies above 30 MeV), the habitability module will be designed to provide protection for the crew against these high energy solar particle events.

The highest energy particles arrive at the Earth approximately 20 minutes after the observed occurrence of a large flare on the Sun. Given the current inexact science in predicting the occurrence of high energy solar particle events with a lead time more than the approximate 20 minutes between the observed occurrence of the event on the Sun and arrival at Earth, provisions will be developed to assure the crew's safety during EVA. (See sections 1.7.1 and 2.8.3 of NASA TM 82478.)

5.4 Electromagnetic Radiation

Design flux levels for the various spectral bands in the solar spectrum are given in section 1.5.3 of NASA TM 82478. However, the high flux levels for the radio frequency (RF) spectral regions is primarily a result of man made Earth based and on-board radiation sources. Therefore, NASA SP-8092, "Assessment and Control of Spacecraft Electromagnetic Interference" June 1972 shall be consulted to insure that an adequate EMI control program results to permit accomplishment of the SSPE operational requirements.

6.0 METEOROIDS

The SSPE's will be designed to prevent loss of functional capability for all items critical to maintaining crew safety and minimum operational support. The SSPE's will otherwise be designed for at least a 0.95 probability of no penetration using a minimum 10 year on-orbit reference design lifetime. The meteoroid flux model given in Figure 2-14, page 2-22, of NASA TM 82478 will be used (see section 2.6 of NASA TM 82478). It is further defined in NASA SP-8013, "Meteoroid Environment Model."

The logarithmic cumulative flux distribution model for the sporadic meteoroid population is given by the expressions:

a) $\mathrm{Log}_{10}N = -14.41 - 1.22\ \mathrm{Log}_{10}m$; for $10^{-6} < m \leq 10$

b) $\mathrm{Log}_{10}N = -14.34 - 1.58\ \mathrm{Log}_{10}m - 0.063\ (\mathrm{Log}_{10}m)^2$; for $10^{-12} < m \leq 10^{-6}$

where N is the cumulative flux, $m^{-2}\ s^{-1}$ (2π st) and m is mass, g. The sporadic flux is omnidirectional and the SSPE in orbit will be partially shielded by the Earth. The extent of the shielding is a function of altitude, and the shielded flux is equal to $\left(\frac{1+\cos\theta}{2}\right)N$ where:

$$\sin\theta = \frac{R}{R + H}$$

R = Radius of the Earth

and H = altitude of SSPE above Earth's surface.

The average hourly rate of meteoroids increases at times during a calendar year due to meteoroid streams as previously noted. Their periods of activity and peak fluxes are given in Table 2-3, page 2-20, of NASA TM-82478, where Fmax is the ratio of the stream to the sporadic meteoroid cumulative flux levels. Note that there is little or no enhancement of the sporadic population for masses less than 10^{-6} gm during stream activity.

Meteoroids are assumed to be spherical in shape and to have a bulk mass density of 0.5 gm/cc. However, this does not apply to micrometeoroids (<50 μ diameter) and it is generally assumed that a density of 2 gm/cc is more appropriate. The average atmospheric entry velocity of sporadic meteoroids is 20 km/sec, which is the value generally used to assess impact damage to spacecraft in Earth orbit. Stream meteoroids generally enter much faster as is seen in Table 2-3, page 2-20, NASA TM-82478.

Space debris has become a significant factor of concern in recent years. Since it is a man-made environment and not a natural environment parameter, it is covered elsewhere in the SSPE requirements. The flux of space debris may exceed that of meteoroids. Therefore, NASA JSC Design Standard 20001 "Orbital Debris Environment for Space Station" should be consulted to insure that an overall SSPE design for both space debris and micrometeoroids damage protection results which will permit accomplishment of the SSPE operational requirements.

6.1 Manned Volumes and Pressure Loss

The SSPE manned volume will be protected from meteoroid impact damage which would result in pressure loss that is critical to the crew's safety.

6.2 Pressure Storage Tanks

The SSPE's pressurized storage tanks will be designed to ensure no toxic gas or liquid leak from meteoroid impact damage.

6.3 Functional Capability

The probability of no penetration shall be assessed on each SSPE in terms of the criticality of loss for its functional capability.

7.0 MAGNETIC FIELD

On-orbit SSPE design torques, surface charges, and induced electrical potential due to operating in the Earth's magnetic field shall be developed based on information given in section 2.7.1 of NASA TM 82478. Additional details are provided in NASA SP-8017, "Magnetic Fields Earth and Terrestrial," and NASA SP-8018, "Spacecraft Magnetic Torques." The International Geomagnetic Reference Field 1980 (see reference 2-32 of NASA TM 82478) will be the basis for the magnetic field model spherical harmonic coefficients. A minimum of 15 terms shall be used in the spherical harmonic expansion to establish SSPE design conditions.

8.0 SPACE THERMAL AND PRESSURE ENVIRONMENT

The space thermal and pressure environment to be used for SSPE's design, including solar radiation, Earth's albedo and radiation, and space sink temperature and pressure, are given in Table 4 (see sections 1.5 and 2.5 of NASA TM 82478).

TABLE 4. SPACE THERMAL AND PRESSURE ENVIRONMENT

Environmental Parameters		Value
Solar Radiation		443.7 ± 1.6 Btu/ft^2-hr
Pressure		10^{-10} Torr
Space Sink Temperature		0°R
Earth Emitted Thermal Radiation	$\Delta t < 0.3$ hr	237^{+28}_{-97} W/m^2
	$0.3 < \Delta t < 3$ hr	237^{+24}_{-48} W/m^2
	3 hr $< \Delta t$	237 ± 21 W/m^2
Albedo	$\Delta t < 0.3$ hr	$0.30^{+0.30}_{-0.15}$ %
	$0.3 < \Delta t < 3$ hrs	0.30 ± 0.10%
	3 hr $< \Delta t$	0.30 ± 0.05%

9.0 PHYSICAL CONSTANTS

The values given in section 1.3 and section 2.3 of NASA TM 82478 will be used for SSPE design performance analyses.

10.0 GROUND HANDLING AND TRANSPORTATION ENVIRONMENTS

The SSPE's and components thereof shall be protected from or designed to accommodate the applicable ambient natural environments for the locations involved in fabrication, storage, transportation, and assembly as given in NASA TM 82478 to insure no adverse natural environment impacts on the SSPE's operational performance.

APPROVAL

NATURAL ENVIRONMENT DESIGN CRITERIA FOR THE SPACE STATION DEFINITION AND PRELIMINARY DESIGN (SECOND REVISION)

By William W. Vaughan and Claude E. Green

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

CLAUDE E. GREEN
Chief, Atmospheric Effects Branch

WILLIAM W. VAUGHAN
Chief, Atmospheric Sciences Division

GEORGE F. McDONOUGH
Director, Systems Dynamics Laboratory

CONCURRENCE:

LUTHER E. POWELL
Manager, Space Station Projects Office