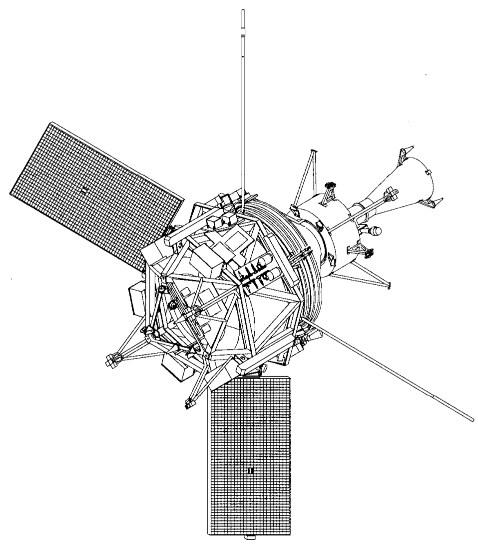
Relativity Mission (GP-B)

Natural Orbital Environment Specification

P0149 Rev B



Stanford University
Relativity Gyroscope Program

03 December 2002

Contract NAS8-36125

National Aeronautics and
Space Administration

George C. Marshall
Space Flight Center, AL 35812

Bob Schultz ______________________
GP-B Systems Engineer

Gaylord Green ___________________
GP-B Program Manager

Barry Muhlfelder __________________
GP-B Technical Manager

C. W. Francis Everitt _______________
GP-B Principal Investigator

Ed Ingraham _____________________
Marshall Space Flight Center

STANFORD

DOCUMENT REVISION RECORD

Document Title: Natural Orbital Environment Specifications

Document Number: P0149
Rev.: B

Document Approved at Rev.: B

Date: 03 December 2002

Authorization for Change	Page	Location	Change Description
PCB 583	2	1.2	Added exception d for GSS performance.

Document Title: Natural Orbital Environment Specifications

Document Number: P0149
Rev.: A

Document Approved at Rev.: A

Date: 14 June 1995

Contents:

(Version Controlled):

Natural Orbital Environment Specifications:

General:

(Note:
This Natural Orbital Environment Specification is intended to describe the naturally occurring environment on orbit only. It does not address interaction between space vehicle systems, such as EMI/EMC or outgassing. In addition, it does not address the launch or ground environments, which are functions of the vehicles and methods employed.

Generally, there are two classes of environments specified. The more severe environments are a "survive only" level during which the spacecraft must avoid permanent damage to any systems or loss of the science experiment but may interrupt collection of data. The less severe environments are a "meet requirements" level during which all space vehicle systems must perform according to specifications.

All environments (in particular, corpuscular radiation) have been presented with a viewpoint of specifying what is present in orbit and not how it applies to any given design. Design-dependent operational characteristics (e.g. Linear Energy Transfer, science gyroscope heating rates, upset rate for digital circuits, noise values for analog circuits, and others) should be derived from the environments specified in the main text based upon the current baseline design. Some derived values are presented in the Appendix for reference.)

The main text of this Specification is under version control and may be changed only through the PCB process as a Type 2 Class 1 PCB. The appendices are presented for information only and may be updated as necessary without need for signatures or PCB approval. Text in italics and enclosed within the pattern *(Note:)* is also presented for information only.

1) Meteoroid and debris strike resistance.

1.1) The Payload and Spacecraft shall withstand without loss of functionality a strike by a meteoroid or debris massing less than 1.0E-4 grams with a closing velocity less than 25 km/sec and density consistent with the mass density distribution for the GP-B orbit.

(Note: A 0.0001 gram meteoroid has an energy of 18 Joules at the most likely closing velocity, 19 km/sec. The total flux of debris plus meteoroids of this mass is 0.09 particles/meter^2/year in the nominal science mission orbit according to NASA TM 4527)

1.2) The Payload and Spacecraft shall continue the science mission with possible loss of redundant systems in the event a strike by meteoroid or debris with mass in the range 1.0E-4 grams to 0.1 grams, closing velocity less than 25 km/sec, and density consistent with the mass density distribution for the GP-B orbit. There are three exceptions to this:

a) A strike on the outer window of the probe.
b) A strike which perforates the Helium thruster manifolds or plumbing.
c) A strike which perforates the telescope sunshade aft of the point where the light baffles begin to have a constant inside diameter.
d) A strike that directly impacts the primary structure and imparts an impulse greater than 1 kg-m/sec to the Payload GSS control effort.

In any of these cases, performance is on a best-effort basis, with appropriate design precautions in place to minimize risk of mission loss.

(Note: A 0.1 gram meteoroid has an energy of 18000 Joules at a closing velocity of 19 km/sec. The total flux of debris plus meteoroids of this mass is 0.00026 particles/meter^2/year in the nominal science mission orbit according to NASA TM 4527 During the 18-month mission, the probability of a strike by such an object on the manifold is approximately 0.0089, the probability of a window strike is approximately 0.0000098, and the probability of a sunshade strike is approximately 0.0012.)

1.3) As a goal, the Payload and Spacecraft will minimize the risk of data loss or mission failure in the event of strikes by particles massing more than 0.1 gram.

2) Ionizing Radiation

2.1) Corpuscular Radiation

2.1.1) The Spacecraft and Payload shall survive during and meet requirements after exposure to one hour of the instantaneous flux shown in Figure 2.1.1-1. The word “survive” means the Spacecraft and Payload suffer no permanent damage and prevent rotor crash. Interruption of science data collection is permissible but undesirable.

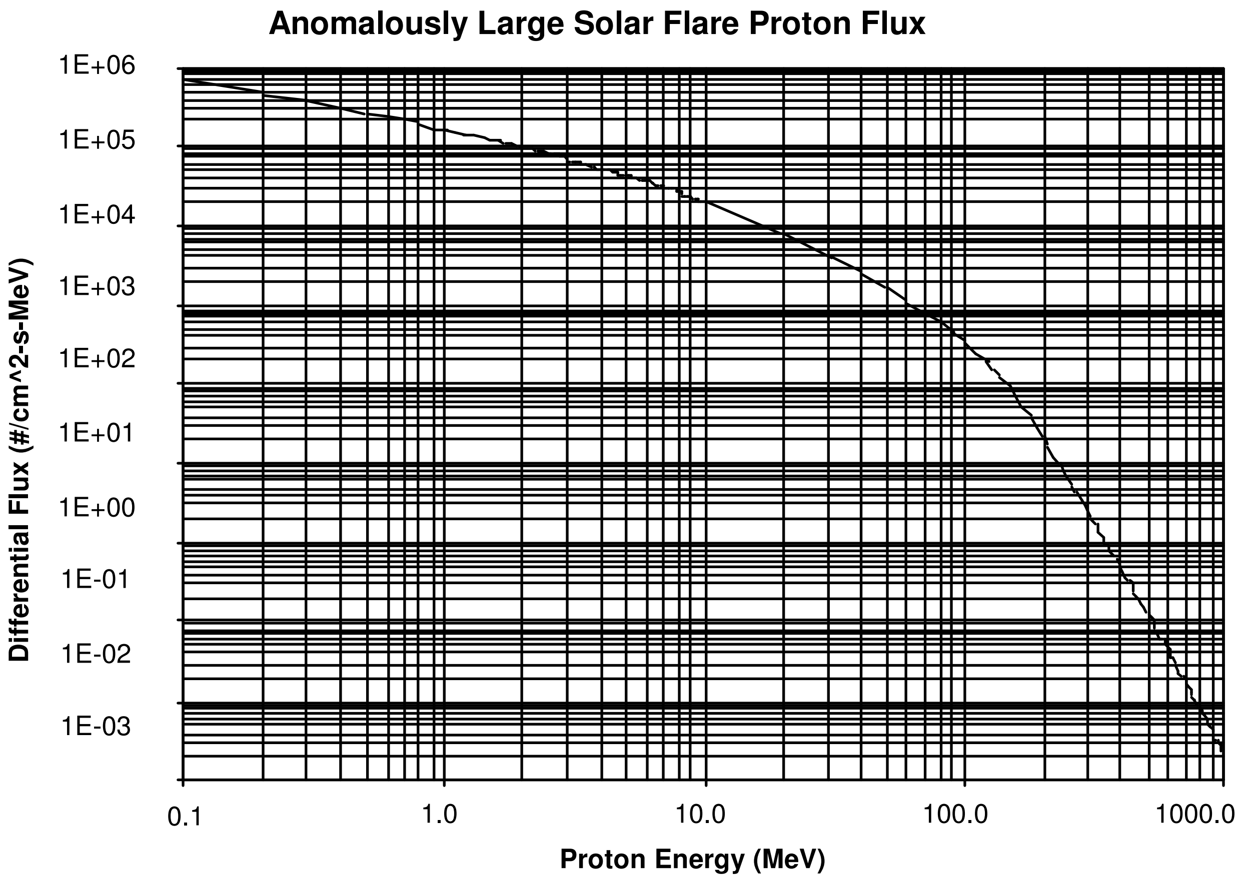


Figure 2.1.1-1 Anomalously Large Solar Flare Proton Flux
. *(from CREME model)*

(Note: Figure to be updated to include flux of heavy ions from solar flare)

(Note: GP-B includes instantaneous flux dependent systems and mission integrated fluence dependent systems. Paragraphs 2.1.1 through 2.1.3 are intended to specify the instantaneous flux environment, while 2.1.4 is intended to specify the mission integrated fluence environment.

2.1.2) The Spacecraft and Payload shall meet requirements for the instantaneous ionizing radiation environments shown in Figure 2.1.2-1 for a 750-km polar orbit. *(which is worse than the 650 km orbit)*

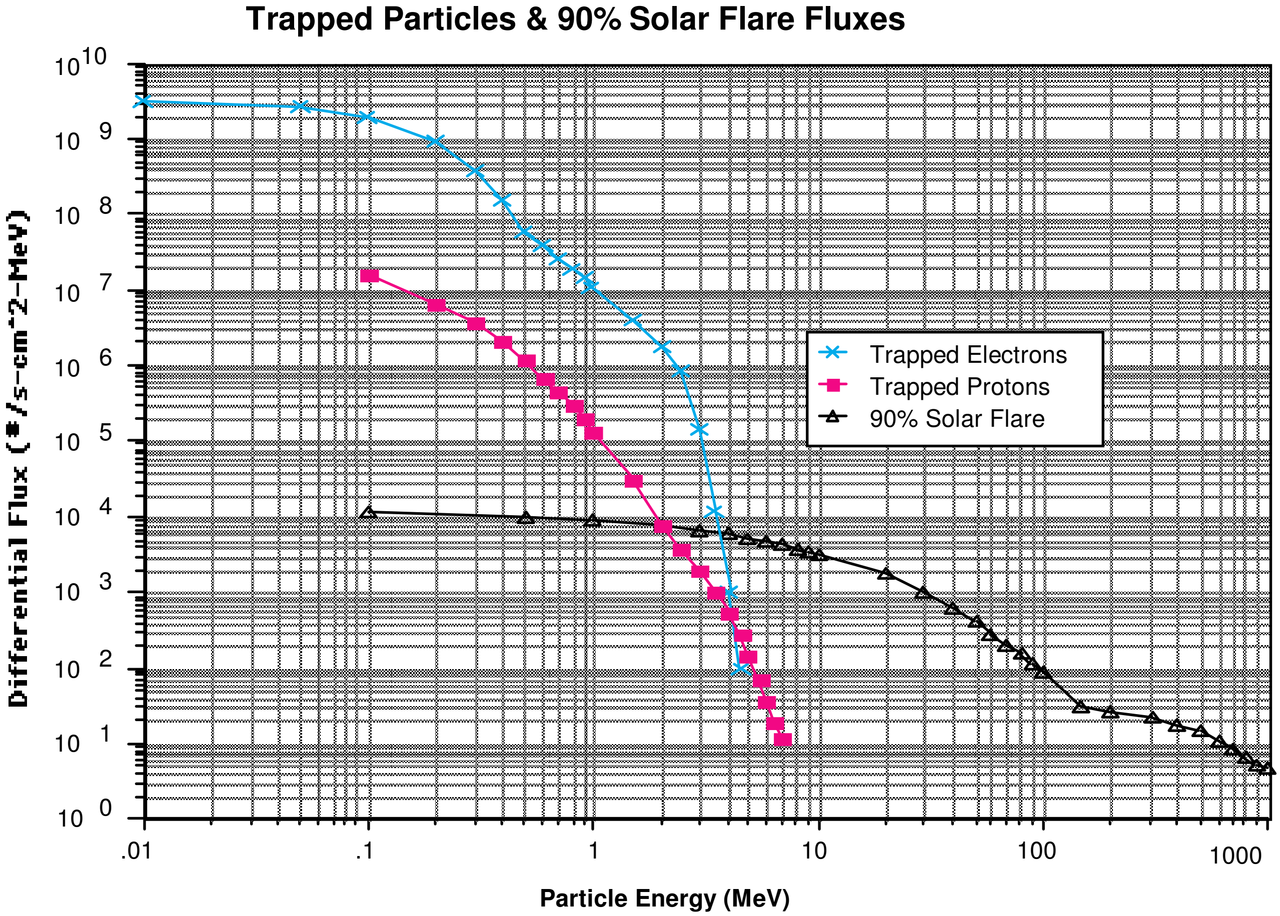


Figure 2.1.2-1 Worst Case Trapped Proton and Electron Flux Environment and 90 % Worst-case Solar Flare Flux for Protons Only. (#/cm2-sec-MeV) .

(trapped particles from AP8MIN and AE8MAX; solar flare protons from CREME model)

2.1.3) The Spacecraft and Payload shall meet requirements for the 90th percentile Galactic Cosmic Ray Flux environments shown in Figure 2.1.3-1 for a 750-km polar orbit. *(which is worse than the 650 km orbit)*

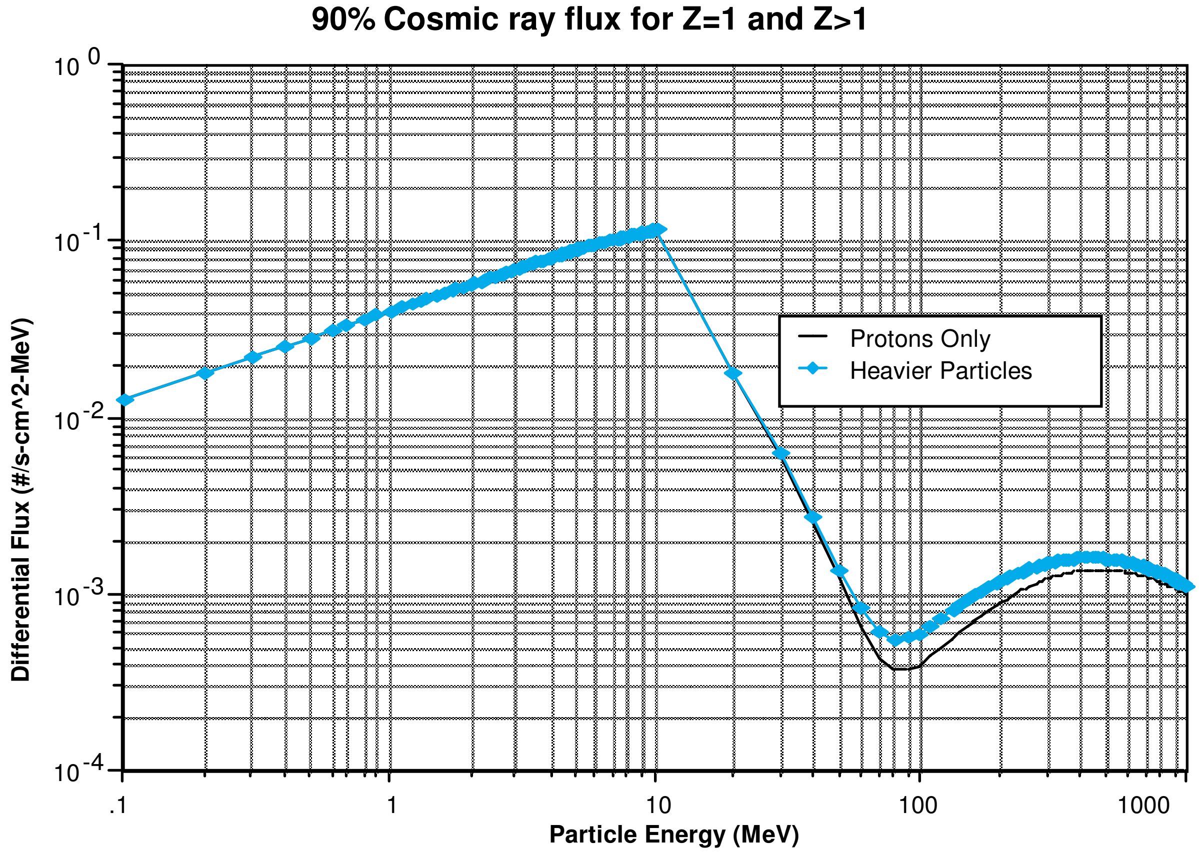


Figure 2.1.3-1 90 % Worst Case Galactic Cosmic Ray Flux for Protons Only (Z=1) and for Heavier Nuclei (Z>1). *(from CREME model)*

2.1.4) The Spacecraft and Payload shall meet requirements for the mission life ionizing radiation environments shown in Figure 2.1.4-1 for a 750-km polar orbit. *(which is worse than the 650 km orbit):*

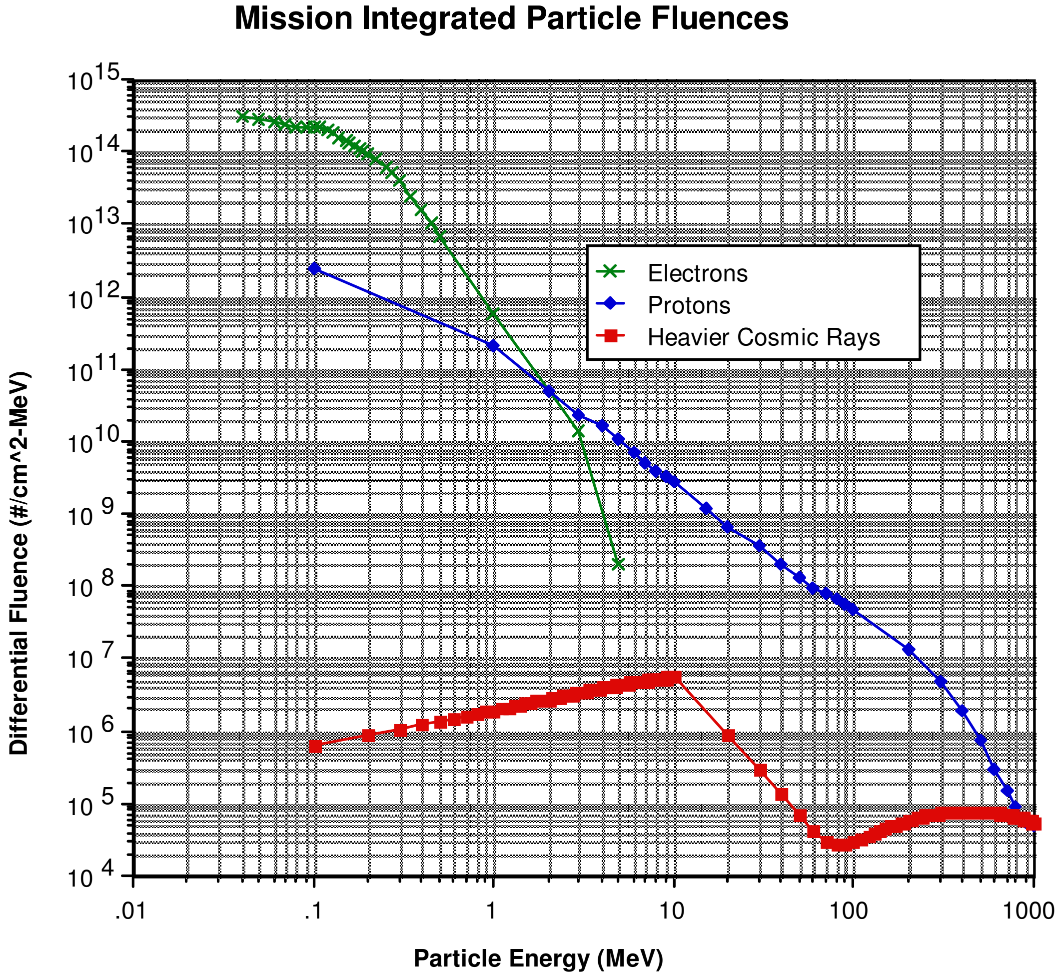


Figure 2.1.4-1 90 % Worst Case Galactic Cosmic Ray Total Mission Fluence for Heavier Nuclei, Total Proton Fluence Over Mission Life, and Total Electron Fluence Over Mission Life.

(Note: Cosmic ray protons and heavier nuclei from CREME model, proton fluence from AP8MIN and SPE91, and electron fluence from AE8MAX)

2.2) Maximum Solar X-ray flux

The Payload and Spacecraft shall meet requirements in the presence of solar flare generated X-ray flux up to 1.0E-3 Watts per square meter.

2.3) Maximum Solar Ultraviolet flux

The Payload and Spacecraft shall meet requirements for the solar spectrum shown in Figure 2.3-1 *(which is Figure 6-3 on page 6-3 in TM4527).*

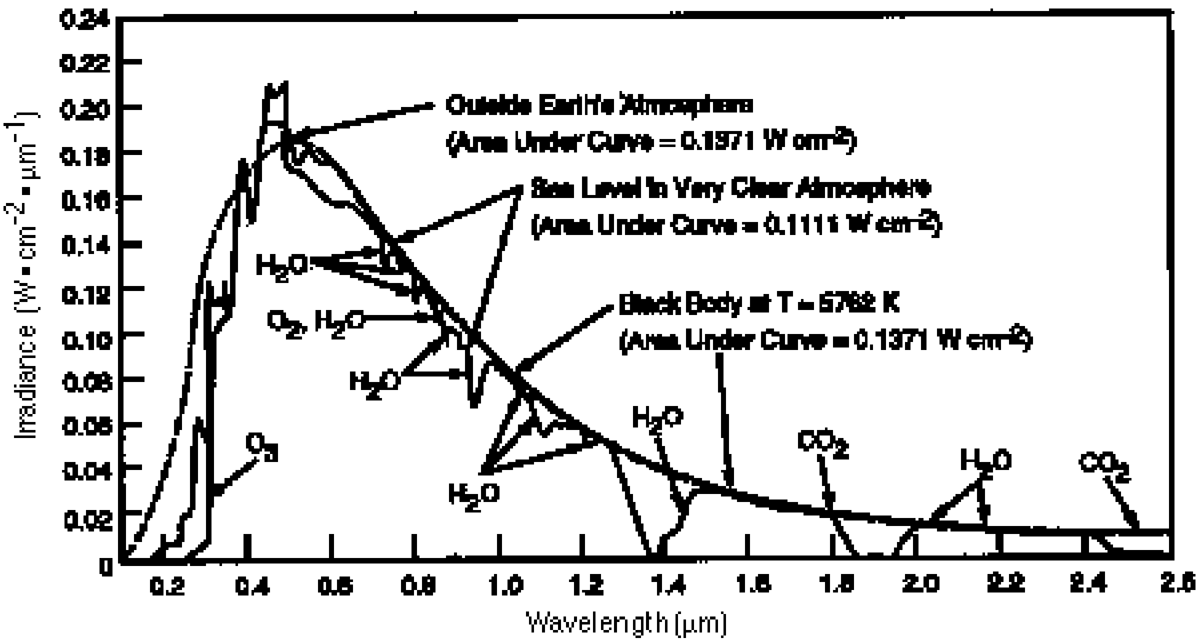


Figure 2.3-1 Solar Spectrum

3)EMI

The Payload and Spacecraft shall meet requirements in the normal EMI environment found in the science mission orbit. Components of this environment include 3.1 through 3.3 below.

3.1) ULF (subauroral) radiation as intense as 0.1 Watts per square meter per Hertz at frequencies below 1 Hz

3.2) Natural Earth and solar system radiation sources from 1.0E-8 Watts per square meter per Hertz at 100 Hz to 1.0E-20 Watts per square meter per Hertz at 10 MHz

3.3) Galactic radiation at 1.0E-18 Watts per square meter per Hertz above 10 MHz.

3.4) The Payload and Spacecraft shall survive brief periods (<1 minute) of irradiation by narrow band signals in the 0.2-10 GHz range emanating from the Earth with field strengths as high as 50 V/m. The word “survive” means the Spacecraft and Payload suffer no permanent damage and prevent rotor crash. Interruption of science data collection is permissible but undesirable.

4) Atmospheric (Neutral) particles

4.1)The Spacecraft and Payload shall meet requirements in a global average density up to 9.723 e-13 kg/m^3 over the life of the mission.
Global atmospheric density may be assumed to vary according to the formula d = (max density) (0.625 + 0.375 cos (SZA)) where SZA is the Solar Zenith Angle.

(Note: According to this formula the peak (subsolar point) density for these conditions is 1.56 e-12kg/m^3 and the minimum (midnight) density is 0.39 e-12kg/m^3. This global average density is the 95% density given in an addendum to TM-4527.)

4.2) The Spacecraft and Payload shall meet requirements in a maximum density from 1.56 e-12 kg/m^3 to 3.56 e-12 kg/m^3 except that pointing requirements will be relaxed to the specified values for Guide Star Invalid conditions.

(Note: The global maximum density given is the100 percentile maximum atmosphere from TM-4527, Appendix C.)

5) Thermal Environment

The Payload and Spacecraft shall meet requirements in a thermal environment determined by the following factors:

5.1) Solar radiation: solar constant of 1371 +/- 10 Watts per square meter
Seasonal modulation of +/- 3.4%
Eclipsed by the Earth between 0% and 36% of each orbit
depending on season and Guide Star Right Ascension.

5.2) Outgoing Long-wave Radiation (OLR) from the Earth corresponding
to a blackbody spectrum for a 288K body,
Intensity from 188 to 282 Watts / sq. meter for 128-second averages
Intensity from 205 to 250 Watts / sq. meter for orbital averages

5.3) Albedo for the Earth with the spectrum of a 5762K blackbody
albedo factor from 0.10 to 0.42 for 128-second averages
albedo factor from 0.19 to 0.34 for orbital averages
(All albedo factors assume zero solar zenith angle and
must be corrected for orbit.)

For combinations of the above values, the hot case design point assumes seasonal sun, extreme hot for the second most significant parameter, and median value for the least significant parameter. Similarly the cold case calculations assumes seasonal sun, extreme cold and median for parameters in order of significance.

The Payload and Spacecraft shall meet lifetime requirements in a thermal environment determined by the seasonal solar input listed above and mean values for albedo and outgoing long-wave radiation.

(Note: the thermal environment values are the 3% and 97% cases from TM4527.)

6) Plasma Environment

6.1) The Spacecraft and Payload shall meet requirements while encountering ionospheric plasma with ion and electron number densities up to 3.0E11 per cubic meter and down to 6E9 per cubic meter and energies corresponding to a Maxwellian thermal energy distribution with an effective temperature of 3500K.

6.2) The Spacecraft and Payload shall meet requirements while encountering auroral plasma with number densities up to 1.0E6 per cubic meter at energies up to 10 keV for electrons and ions.

6.3) The Spacecraft and Payload shall meet requirements in the presence of atomic oxygen in concentrations up to 1.8E7 per cubic centimeter.

6.4) The Spacecraft and Payload shall meet requirements in the presence of auroral electron flux up to 1.0E9 electrons per square centimeter per steradian per keV at energies up to 20 keV.