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Project

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Telescope Concept Study
Interface and Constraints Document

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1.0 Introduction

This document specifies initial interface, functional and performance requirements for the JDEM Telescope Concept Study. It is a starting point for use by the contractors in deriving detailed telescope requirements and interface requirements to both the instrument and spacecraft.

2.0 Reference Documents

At the website http://jdem.gsfc.nasa.gov, documents relating to this study are available for review and download.

JDEM-TELE-LEGL-0008	JDEM Project Telescope Statement of Work
JDEM-TELE-LIST-0002	JDEM Project Telescope Concept Study DILS
JDEM-TELE-REF-0010	JDEM Project Telescope Concept Study Payload Description
JDEM-SE-REF-0011	JDEM Project Math Models Guidelines Document

3.0 General

3.1 Interface Definitions

The JDEM optical telescope assembly (OTA) provides the front end to the NASA GSFC designed NIR instrument and the Fine Guidance Sensor (FGS). The OTA consists of the aft metering structure, which provides mounting locations for the telescope primary mirror and support structure for the telescope optics, the NIR instrument and the fine guidance sensor; the forward metering structure, which supports the secondary mirror; and the outer baffle assembly (OBA), which includes the telescope cover. The OTA mounts to the top of the hexagonal spacecraft bus at up to six available mount locations. The OBA provides mounting locations for the NIR cryogenic radiator and provides lifting points for the Observatory. The spacecraft provides mounting locations for the instrument and telescope electronics. The OTA, NIR instrument and FGS are called the payload. The payload and the spacecraft form the observatory. Figure 3-1 depicts the JDEM observatory interfaces.

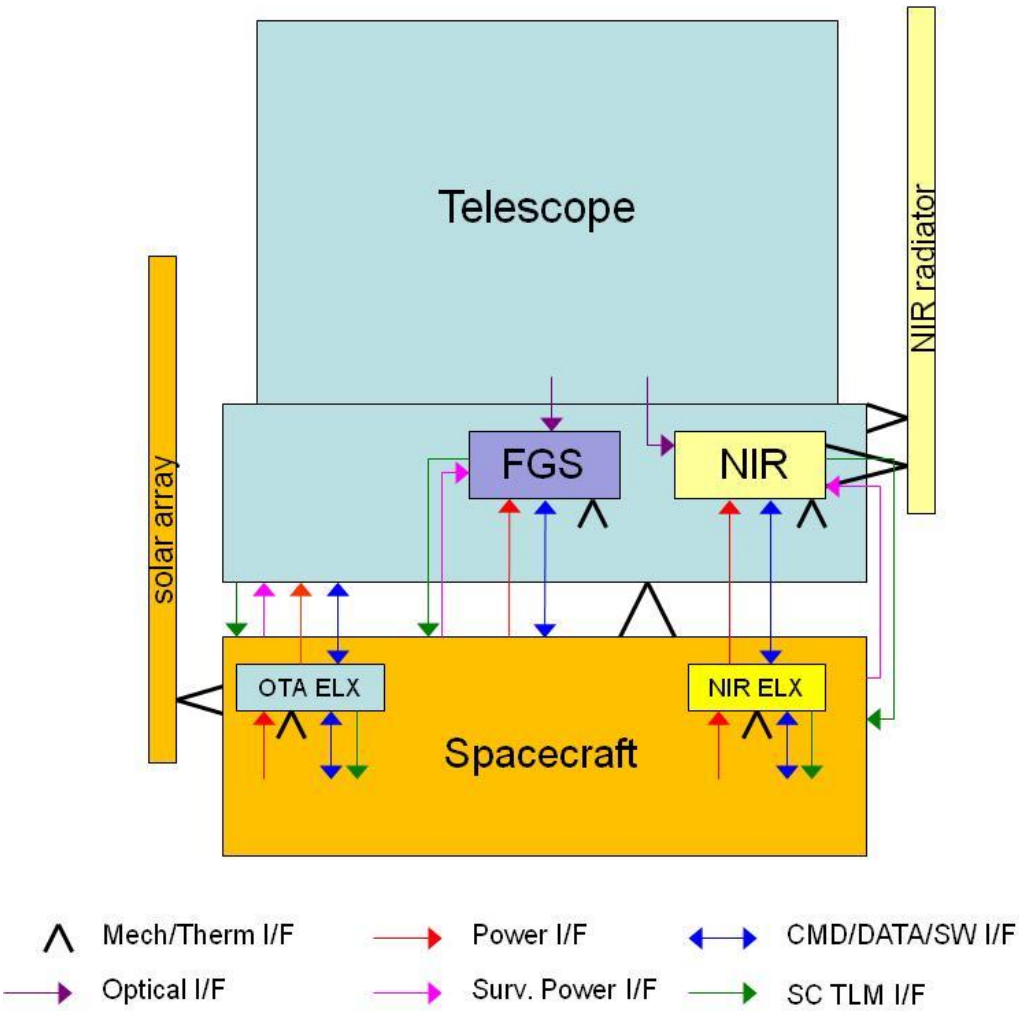

Figure 3-1 JDEM Observatory Interface Diagram

3.2 Coordinate Systems

3.2.1 Observatory Coordinate System

The observatory uses a right-handed coordinate system fixed in the observatory body, as shown in Figure 3-2. The origin of the body-fixed observatory coordinate system lies in the separation plane of the launch vehicle Payload Attachment Fitting (PAF). The X-axis is collinear with the geometrical centerline of the observatory. The +X direction lies along the center of the telescope field of view. The Z-axis is collinear with the sun/anti-sun line. The +Z axis is the sun side. The +Y-axis is the cross-product of the +Z-axis and the +X-axis. The terms Roll axis, Pitch axis, and Yaw axis refer to the X, Y, and Z observatory axes, respectively.

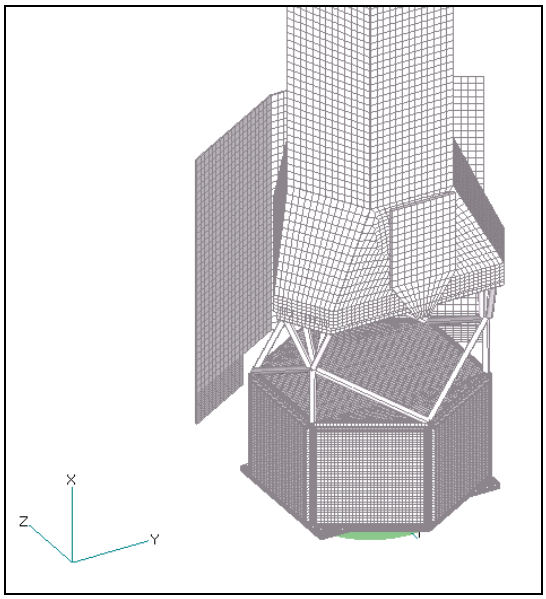

Figure 3-2 Observatory Coordinate System

3.2.2 Payload Coordinate System

The payload uses a right-handed coordinate system fixed in the payload body, as shown in

Figure 3-3. The origin of the payload coordinate system lies at the virtual vertex of the telescope primary mirror. The Z-axis is collinear with the geometrical centerline of the observatory. The +Z direction points into the telescope baffle. The X-axis is collinear with the sun/anti-sun line. The +X axis is the sun side. The +Y-axis is the cross-product of the +Z-axis and the +X-axis.

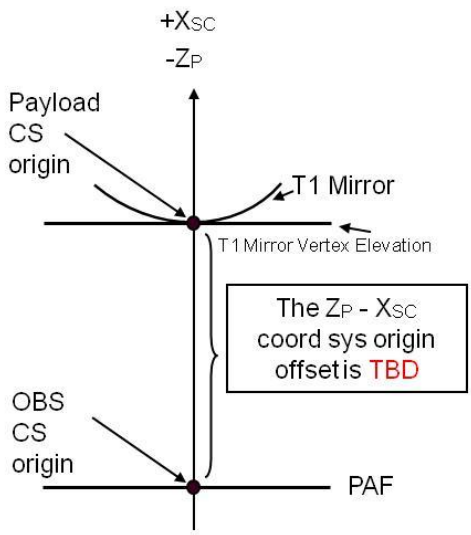

Figure 3-3 Payload Coordinate System

3.3 Units

The international system of Units (SI Units) shall be used throughout the JDEM Project, including in all models exchanged, and are shown in Table 3-1 below. Engineering and manufacturing drawings using both English units and SI units are acceptable for manufacturing purposes.

Quantity	Name	Symbol	Variations
Length	Meter	m	mm, (10^{-3}m)
Mass	Kilogram	kg	G, (10^{-3}kg)
Time	Second	s	ms (10^{-3}s)
Power	Watts	W	mW, (10^{-3}W)
Temperature	Kelvin	K	mK (10^{-3}K)
Pressure	Pascal	Pa	kPa (10^{3}Pa)

Table 3-1: Common SI Units Used In This Document

4.0 Mechanical Interfaces and Constraints

4.1 Envelopes

4.1.1 OTA Static and Dynamic Envelope

The OTA shall be designed so there are no static or dynamic protrusions beyond the physical envelope showed in figure TBD.

4.1.2 NIR Accommodation

The NIR instrument envelope is shown in figure TBD. The OTA shall interface to the NIR instrument without violating the envelope of the NIR instrument.

4.1.3 FGS Focal Plane Accommodation

The FGS focal plane envelope is shown in figure TBD. The OTA shall interface to the FGS focal plane without violating the envelope of the FGS focal plane.

4.2 Mounting

4.2.1 Kinematic Mounts

The OTA interface to the spacecraft bus shall have a kinematic mounting scheme such that distortions of the spacecraft bus can only induce rigid body motions to the OTA.

4.2.2 Mounting Hardware

The OTA shall provide all mounting brackets and hardware required to mate the OTA to the spacecraft.

4.2.3 NIR Instrument Mounting Interface

The OTA shall provide an interface structure to mount the NIR instrument to the OTA using the mounting locations defined in Figure (TBD). The mounting brackets and hardware to mount the NIR instrument to the OTA will be provided by the NIR instrument.

4.2.4 NIR Instrument Interface Mounting Forces

The OTA shall be capable of reacting forces at the NIR mounting interfaces not to exceed (TBD).

4.2.5 NIR Instrument Radiator Mounting Interface

The OTA shall provide an interface structure to mount the NIR instrument radiator to the OTA using the mounting locations defined in Figure (TBD). The mounting brackets and hardware to mount the NIR instrument radiator to the OTA will be provided by the NIR instrument.

4.2.6 NIR Instrument Radiator Interface Mounting Forces

The OTA shall be capable of reacting forces at the NIR radiator mounting interfaces not to exceed (TBD).

4.2.7 FGS Focal Plane Mounting Interface

The OTA shall provide an interface structure to mount the FGS focal plane to the OTA using the mounting locations defined in Figure (TBD). The mounting brackets and hardware to mount the NIR instrument radiator to the OTA will be provided by the NIR instrument.

4.2.8 FGS Focal Plane Interface Mounting Forces

The OTA shall be capable of reacting forces at the FGS focal plane mounting interfaces not to exceed (TBD).

4.2.9 NIR Ground Access

The OTA shall provide access to install or remove the NIR Instrument without removing or disconnecting any NIR Instrument or other science instrument hardware.

4.3 OTA Mass Properties

4.3.1 OTA Mass

The maximum mass of the OTA shall be 1000 (TBD) kg.

4.3.2 OTA Axial Center of Gravity

The maximum center of gravity (CG) height of the OTA shall be less than TBD meters from the origin of the observatory coordinate system. The distance from the origin to the top of the spacecraft bus is 2146.3 mm.

4.3.3 OTA Lateral Center of Gravity

The maximum lateral CG of the OTA shall be less than TBD meters off of the X-axis.

4.3.4 Moments of Inertia

The maximum launch moments of inertia of the OTA, about the TBD, shall be constrained to $Ixx \leq$ (TBD) kg-m^2, $Iyy \leq$ (TBD) kg-m^2, $Izz \leq$ (TBD) kg-m^2, $|Ixy| \leq$ (TBD) kg-m^2, $|Ixz| \leq$ (TBD) kg-m^2, and $|Iyz| \leq$ (TBD) kg-m^2.

4.3.5 Instrument Mass Properties Data

For OTA structural analysis, the NIR instrument mass is TBD kg. The CG location is as shown in Figure TBD.

4.3.6 FGS Focal Plane Mass Properties Data

For OTA structural analysis, the FGS mass is TBD kg. The CG location is as shown in Figure TBD.

4.4 Alignment

4.4.1 Observatory Pointing Knowledge

The Observatory pointing knowledge shall be less than 4 milli-arcseconds (TBD) RMS, per axis for the VNIRI.

4.4.2 Observatory Jitter

The Observatory jitter shall be less than 40 milli-arcseconds (TBD) RMS, per axis for the VNIRI.

5.0 Thermal Interfaces and Constraints

This section defines the thermal interfaces and configuration of the Joint Dark Energy Mission (JDEM) observatory. The parameters needed to generate thermal models of the Optical Telescope Assembly (OTA) and the NIR instrument radiator are provided. The specific interface design and performance requirements are specified.

GSFC will provide very simple thermal models of the TBD side of the bus, the solar array, the FGS and the NIR instrument, including the radiator. These models shall be used with the provided boundary temperatures. These simple models shall be used to account for radiation exchange couplings.

5.1 OTA Thermal Interfaces

5.1.1 OTA Thermal System

The design and performance of the OTA thermal system shall be the responsibility of the OTA provider.

5.1.2 NIR Instrument Thermal System

The design and performance of the NIR Instrument and radiator shall be the responsibility of the NIR Instrument provider.

5.1.3 FGS Focal Plane Thermal System

The design and performance of the FGS focal plane shall be the responsibility of the FGS focal plane provider.

5.1.4 Spacecraft Thermal System

The design and performance of the spacecraft thermal system shall be the responsibility of the spacecraft provider.

5.1.5 OTA Heat Transfer

The OTA shall be conductively and radiatively isolated from the spacecraft and instruments.

5.1.6 OTA Conductive Thermal Isolation

The OTA shall provide all thermal isolation between the OTA and the spacecraft.

5.1.7 NIR Instrument Heat Transfer

The NIR Instrument shall be conductively and radiatively isolated from the OTA and spacecraft.

5.1.8 NIR Conductive Thermal Isolation

The NIR Instrument shall provide all thermal isolation between the NIR Instrument and the OTA and the NIR instrument radiator and the OTA.

5.1.9 NIR Instrument Interface Maximum Energy Flow

The NIR Instrument shall limit the conductive energy flow between the NIR Instrument and the OTA to less than (TBD) W at the minimum and maximum NIR Instrument and the OTA instrument cavity temperatures.

5.1.10 NIR Instrument Radiator Interface Maximum Energy Flow

The NIR Instrument shall limit the conductive energy flow between the NIR Instrument radiator and the OTA to less than (TBD) W at the minimum and maximum NIR Instrument radiator and the OTA instrument cavity temperatures.

5.1.11 FGS Focal Plane Heat Transfer

The FGS focal plane shall be conductively and radiatively isolated from the OTA and spacecraft.

5.1.12 FGS Focal Plane Thermal Isolation

The FGS focal plane shall provide all thermal isolation between the FGS focal plane and the OTA.

5.1.13 FGS Focal Plane Interface Maximum Energy Flow

The FGS shall limit the conductive energy flow between the FGS focal plane and the OTA to less than (TBD) W at the minimum and maximum FGS focal plane and the OTA instrument cavity temperatures.

5.1.14 OTA Radiative Thermal Isolation

All OTA surfaces facing the NIR instrument, NIR instrument radiator and the FGS focal plane, excluding the optical surfaces, shall be covered with Multi-Layer Insulation (MLI).

5.1.15 Exceptions

Any exceptions shall be approved by the GSFC.

5.1.16 Radiative Heat Leak

The OTA shall calculate the radiative heat leak through the MLI at the minimum and maximum NIR Instrument, FGS and OTA instrument cavity temperatures assuming a blanket effective emissivity of TBD.

5.2 OTA Temperature and Gradient Requirements

5.2.1 OTA Optics Temperature

All OTA optics must be maintained at less than or equal to 243 K.

5.2.2 OTA Optics Radial Gradient

The gradient across the surface of the OTA optics shall be less than TBD K.

5.2.3 OTA Optics Axial Gradient

The gradient between the front and back surfaces of the OTA optics shall be less than TBD K.

5.2.4 Instrument Cavity Temperature Range

The OTA shall maintain the instrument cavity within the temperate range of (TBD)K and (TBD)K.

5.3 Thermal Model Boundary Conditions

The thermal analyses shall only use boundary (fixed-temperature) nodes for the hardware and at the temperatures specified below. The NIR instrument thermal zones are shown in figure TBD.

Deep Space:	7 K
SC Bus:	263 K-323 K
NIR Instrument Temps	
Zone 1	140 K-180 K
Zone 2	100 K
Radiator	TBD K
Solar Array Temps	343 K-373 K

5.4 Thermal Environment

The thermal analyses shall use the following thermal environment.

Solar Constant	1262 W/m^2 - 1391 W/m^2
Earth Albedo	N/A
Earth IR	N/A
L2 Orbit (distance from Earth)	1609340 Km

5.5 NIR Instrument Optical Properties

Thermal analyses shall use the following optical properties for the NIR instrument

Zone 1:	α = TBD, ε = TBD
Zone 2:	α = TBD, ε = TBD
Radiator Front:	α = TBD, ε = TBD
Radiator Sides:	α = TBD, ε = TBD

5.6 FGS Focal Plane Optical Properties

Thermal analyses shall use the following optical properties for the FGS focal plane

TBD: α = TBD, ε = TBD

5.7 Thermal Model MLI Coverage

The GSFC provided thermal model has MLI on the following surfaces:

The top (TBR) of the spacecraft bus

The solar array side facing the OTA

The NIR instrument surfaces facing the OTA with the exception of the surface representing the payload aperture

The NIR instrument radiator non-radiating surfaces

6.0 Optical Interfaces and Constraints

6.1 Pupil Interface Requirements

6.1.1 Visible NIR Imager (VNIRI) Pupil Interface

The VNIRI pupil is in a converging beam at f/13.75. The pupil size is 85 mm diameter. The telescope (PM, SM, fold, imaging TM) shall deliver a beam aligned to this pupil over the field of view and within the budget in the following section. The thermal transition from ~243K telescope temperature to ~140K VNIRI instrument temperature happens just before the pupil, i.e. the pupil mask is the first cold element in this optical train. Also the mechanical interface between the telescope and VNIRI is at this same interface.

6.1.2 NIR Spectrometer (NIRS) Pupil Interface

The NIRS pupil is in a collimated space, provided by the collimator fore optics of the telescope. Collimated wavefront quality is per the following section. The mechanical, optical and thermal interface is similar, other than collimation, to the VNIRI pupil interface.

6.2 Wavefront Error Budget

6.2.1 Wavefront Error Allocations

Figure 6-1 and Figure 6-2 provide the wavefront error allocations for the VNIRI and the NIRS in nm, RMS. The yellow values apply to the telescope. The rest of the budget is supplied here for reference, values are TBR. This portion is the overall budget primarily aimed at static errors.

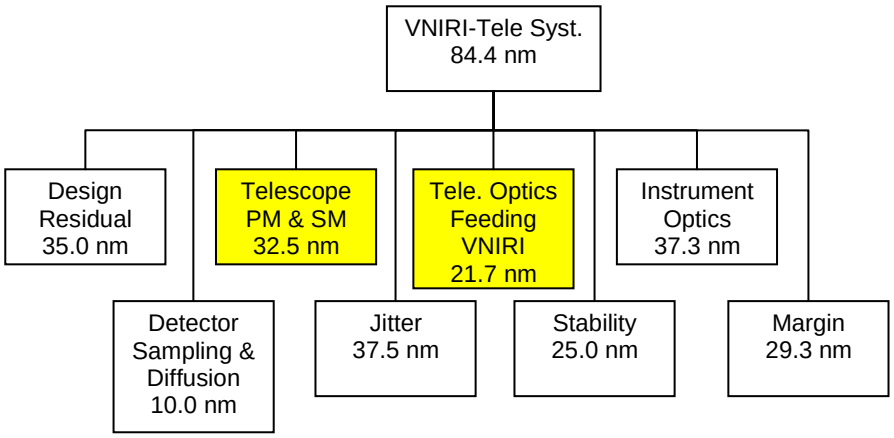

Figure 6-1 VNIRI Wavefront Error Budget

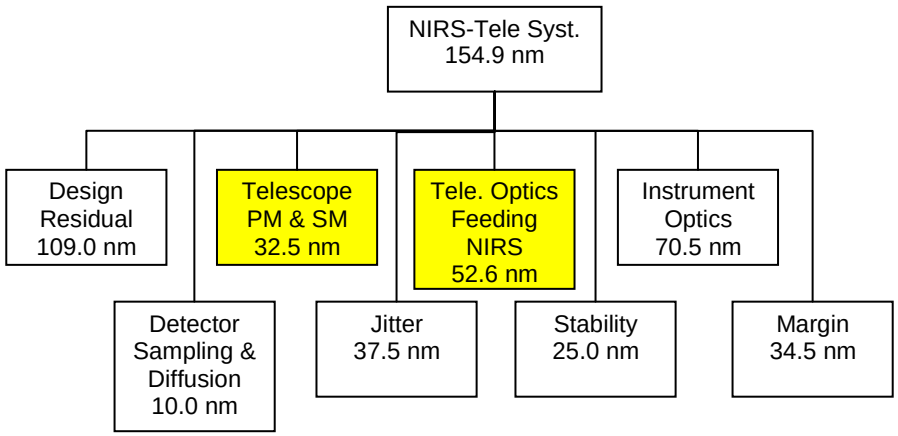

Figure 6-2 NIRS Wavefront Error Budget

6.2.2 Stability Definition

The point spread function (PSF) needs to be highly stable in the VNIRI channel to enable weak lensing (WL) galaxy shape measurements. The following definitions shall apply for the purpose of defining the stability requirement for the VNIRI:

$$M \equiv \int P(x,y)W(x,y)dxdy$$

$$\bar{x} \equiv (1/M)\int xP(x,y)W(x,y)dxdy$$

$$\bar{y} \equiv (1/M)\int yP(x,y)W(x,y)dxdy$$

$$P_{xx} \equiv (1/M)\int (x-\bar{x})^2 P(x,y)W(x,y)dxdy$$

$$P_{yy} \equiv (1/M)\int (y-\bar{y})^2 P(x,y)W(x,y)dxdy$$

$$P_{xy} \equiv (1/M)\int (x-\bar{x})(y-\bar{y})P(x,y)W(x,y)dxdy$$

Where W is a Gaussian weighting factor with σ ~0.23 arcsec {typical galaxy target size}, such that

$$W \equiv \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right)$$

6.2.3 Stability Requirement

The P_{xx}, P_{yy}, P_{xy} variations shall be <0.1% of (P_{xx} + P_{yy}) over one observation {roughly 150 sec}.

6.3 Stray Light

The OTA shall keep stray light contributions to less than or equal to $1.0e^{10}$ W/m^2 (~10% of the minimum zodiacal light contribution), other than a very small (TBD arcsec) area around any very bright stars (m_v≤10) in the field of view.

6.4 Telescope Collecting Area Obscuration

The OTA shall maintain the obscured collecting area to less than 15 – 30% (TBR).

7.0 Environments

7.1 Structural Environmental Design Constraints

The design of the structure shall survive the ground, launch, and operational structural environments provided below.

7.1.1 Loads

The OTA loads shall be derived from a sinusoidal base drive analysis of the observatory finite element model (FEM) consisting of the provided spacecraft and solar array models, and the OTA FEM proposed from this study.

The OTA FEM shall be adjusted to have the maximum mass allocation and CG height as defined in Section 4.3. The sinusoidal spectra defined in Section 7.1.3 shall be applied to the observatory FEM in all three axes, one axis at a time. The loads may be notched so that the observatory base bending moment does not exceed the level defined by applying the quasi-static design load factors shown in Figure 7-1 to the observatory CG. The analysis shall use a critical damping level of 1.5%.

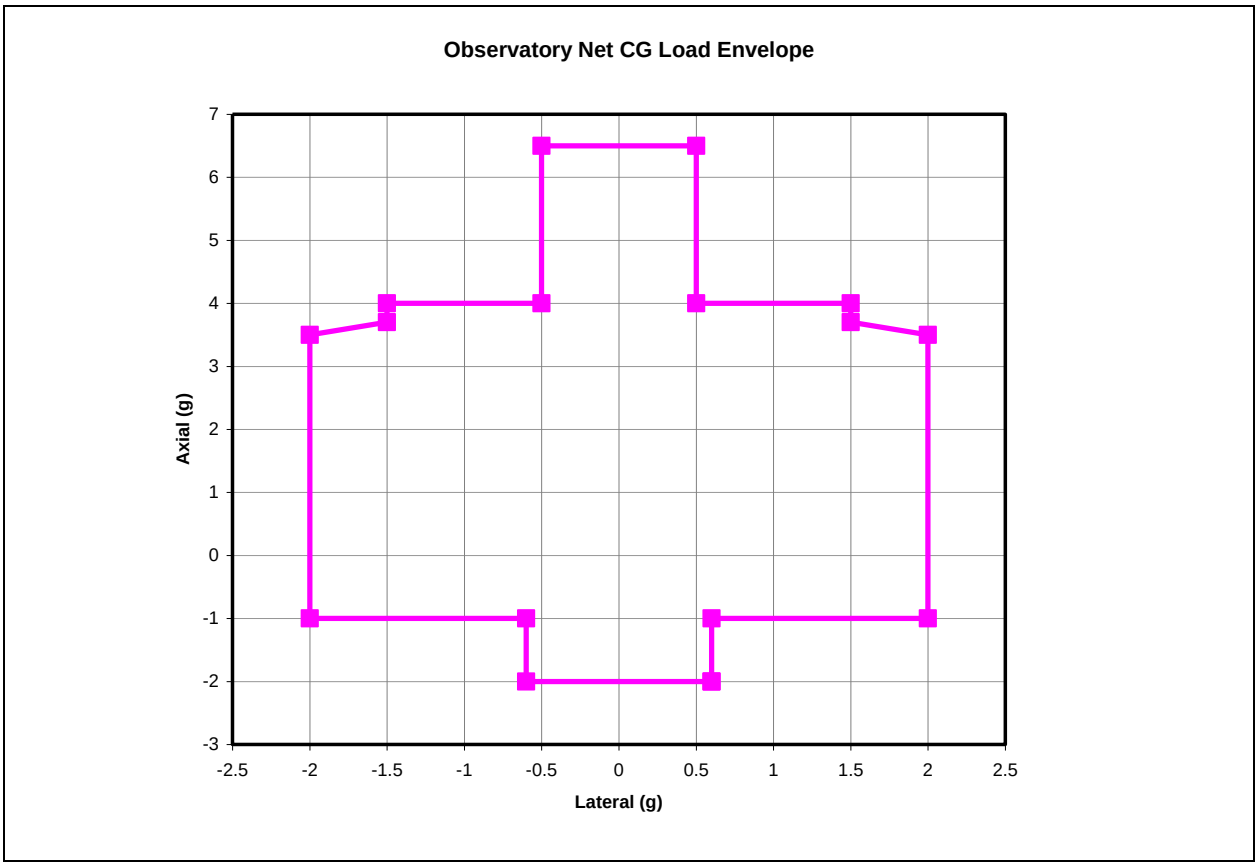

Figure 7-1 Design Load Factors

7.1.2 Frequency

The OTA shall be designed such that when combined with the SC FEM and using NTE mass allocations for the OTA and NIR instrument, the first observatory lateral mode frequency is greater than 10 Hz and the first axial frequency is greater than 27 Hz.

7.1.3 Sinusoidal Vibration

The OTA shall be designed to survive the launch vehicle flight level sinusoidal environment defined in Table 7-1. These levels may be notched according to the criteria defined in Section 7.1.1.

Axis	Frequency (Hz)	Limit Level
Lateral	5 to 25 25 to 100	0.8 g 0.7g
Axial	5 to 100	1.0 g

Table 7-1 Sinusoidal Environment

7.1.4 Vibro-Acoustics

The OTA shall be designed to survive the acoustic environment as defined below in Table 7-2.

Frequency (Hz)	Levels (dB)
25	123.2
32	123.2
40	125.2
50	126.2
63	126.3
80	128.0
100	130.4
125	130.4
160	130.4
200	130.0
250	130.0
315	130.0
400	129.5
500	128.0
630	125.5
800	123.0
1000	121.2
1250	121.2
1600	118.0
2000	116.5
2500	115.0
3150	113.5
4000	112.0
5000	110.5
6300	109.0
8000	109.7
10000	110.5
OASPL	**140.5**

Table 7-2: Acoustic Levels

7.1.5 Shock

TBD

7.1.6 Depressurization

The OTA shall survive depressurization during ascent at rates limited to 2.76 kPa/sec except for a transonic spike to 6.2 kPa/sec. The profile shown in Figure 7-2 can be used as a guideline for depressurization rate vs. time but should be adjusted to reflect peak spike values and limits outside the spike region. A venting analysis shall be conducted to demonstrate that vent area is adequate.

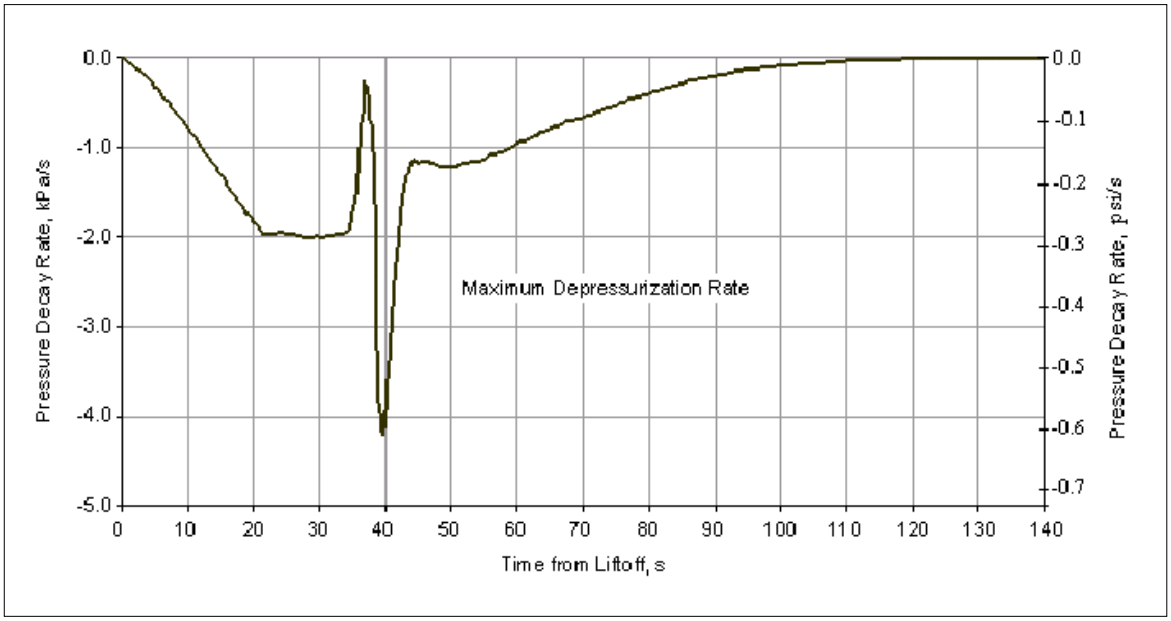

Figure 7-2 Pressure Decay Rate

7.1.7 NIR Instrument Volume

The OTA shall accommodate venting of the NIR instrument during ascent. The NIR instrument volume to be used in the venting analysis is TBD (m^3).

7.1.8 Factors of Safety

The OTA shall demonstrate positive margins of safety using appropriate factors of safety given in the General Environmental Verification Standard (GEVS), GSFC-STD-7000. Table 7-3 reflects the GEVS factors.

Type	Static	Sine	Random/ Acoustic (2)
Metallic Yield	1.25	1.25	1.6
Metallic Ultimate	1.4	1.4	1.8
Stability Ultimate	1.4	1.4	1.8
Beryllium Yield	1.4	1.4	1.8
Beryllium Ultimate	1.6	1.6	2.0
Composite Ultimate	1.5	1.5	1.9
Bonded Inserts/Joints Ultimate	1.5	1.5	1.9

1 - Factors of safety for glass and structural glass bonds specified in NASA-STD-5001
2 - Factors shown should be applied to statistically derived peak response based on RMS level. The peak response is calculated as a 3-sigma value.

Table 7-3 Analysis Factors of Safety (1)

7.2 Electromagnetic, Electrostatic, and Magnetic Requirements

TBD

7.3 Radiation Environment

TBD

7.4 Contamination Control

During Observatory level integration and test, transportation, storage and pre-launch activities, the NIR Instrument shall be maintained in a Class (TBD) environment.

7.5 Ambient Temperature

During Observatory level integration and test, transportation, storage and pre-launch activities, the ambient temperature shall be maintained between (TBD)°C and (TBD)°C.

7.6 Humidity

During Observatory level integration and test, transportation, storage and pre-launch activities, the relative humidity shall be maintained between 30% and 70% (TBD).