Geostationary Extended Observations (GeoXO) Flight Project

Sounder (GXS) Performance and Operational Requirements Document (PORD)

January 31, 2023

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

To verify the correct version of this document, please contact the GeoXO Series Configuration Management Office

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Sounder (GXS)

Performance and Operational Requirements Document (PORD)

Signature page

Prepared by:

Electronically approved by: *01/20/2023*

Nicolaas Du Toit — Date
GeoXO Flight Project, Instrument Systems Engineer
NASA GSFC, Code 418

Reviewed by:

Electronically approved by: *01/25/2023*

Kevin J. Tewey — Date
GeoXO Flight Project, Instrument Manager
NASA GSFC, Code 418

Electronically approved by: *01/26/2023*

Steven W. Bidwell — Date
GeoXO Flight Project, Mission Systems Engineer
NASA GSFC, Code 418

Electronically approved by: *01/09/2023*

Megan Gorham — Date
GeoXO Flight Project, Deputy Mission Systems Engineer
NASA GSFC, Code 418

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Approved by:

Electronically approved by: *01/31/2023*

Monica Todirita
GeoXO Flight Project, Deputy Project Manager (DPM)
NOAA GSFC, Code 418

Date

/GeoXO Flight Project GXS Sounder

GXSPORD

418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B

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ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD1	1	**1 Scope**
GXSPORD2	1.1	**1.1 Identification**
GXSPORD3	1.1.0-1	This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) next generation Geostationary (GEO) - eXtended Observations (GeoXO) hyperspectral radiometric Sounder (GXS). Note that the GXS may incorporate additional capabilities described in the Appendix.
GXSPORD4	1.2	**1.2 Mission Review**
GXSPORD5	1.2.0-1	The GXS is a hyperspectral infrared passive radiometric sounder used to collect environmental data as part of a 3-axis stabilized geostationary (GEO) weather satellite system of the GEO-eXtended Observations (GeoXO) program. The GXS will collect radiance observations of the earth's atmosphere with both spectral and horizontal resolution that will yield vertical temperature and moisture information. Winds can also be derived from rapid mesoscale observations. GXS will provide hyperspectral geostationary operational observations for soundings of the western hemisphere for the first time. GXS data will enhance convective storm nowcasting as well as improve numerical weather prediction (NWP) in short range weather forecasting and longer range weather prediction.
GXSPORD6	1.2.0-2	The GXS mission objectives are to: 1. Provide radiance data that will be used by NOAA and other public and private agencies to produce routine meteorological analyses and forecasts of temperature, moisture, and winds. 2. Provide radiance data to expand knowledge of mesoscale and synoptic scale storm development and improve forecasting of severe weather events. 3. Provide radiance data for the measurement and trending of longer term climate change.
GXSPORD7	1.2.0-3	The GXS instrument, designated as GXS in this document, provides data to the GeoXO Ground System via the spacecraft communication system. The GeoXO Ground System takes the GXS data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates radiometrically calibrated and navigated data (Level 1b) that will be used by NOAA to generate end-products for users. The GeoXO Ground System will implement algorithms developed by the GXS contractor to satisfy GXS performance requirements.
GXSPORD8	1.3	**1.3 Document Overview**
GXSPORD9	1.3.0-1	This document contains all performance requirements for the GXS instrument and Ground Support Equipment (GSE). This document, the General Interface Requirements Document (GIRD), and the GXS Unique Instrument Interface Document (UIID) define all instrument to spacecraft interfaces for the GXS instrument.
GXSPORD10	1.4	**1.4 Terminology**
GXSPORD11	1.4.0-1	The use of "**shall**" designates a requirement that must be met.

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GXSPORD12	1.4.0-2	The use of "should" designates good practice.
GXSPORD13	1.4.0-3	The use of "will" designates a statement of fact or intention of the government.
GXSPORD14	1.4.0-4	The use of "may" designates that permission has been granted by the government.
GXSPORD15	1.4.0-5	The term "(TBS)", which means "to be specified", means that the contractor will supply the missing information in the course of the contract. These serve as a placeholder for future requirements. The contractor is not liable for compliance with these "placeholder" requirements, as insufficient information is provided on which to base a design.
GXSPORD16	1.4.0-6	The term "(TBR)" means "to be refined/reviewed" for a value that is subject to review for appropriateness and is subject to revision. The vendor is liable for compliance with the information marked "TBR" as if the "TBR" notation did not exist.
GXSPORD17	1.4.0-7	The term "(TBD)" means, "to be determined" and is used when no value is available with subsequent study needed to obtain it.
GXSPORD18	1.5	**1.5 Definitions**
GXSPORD19	1.5.0-1	Throughout this document, the following definitions apply:
GXSPORD20	1.5.0-2	Accuracy: Refers to the error in a measurement, which is the difference between the measurement result and the object to be measured (the measured or true value). It includes both systematic and random errors. Systematic errors must be estimated from an analysis of the experimental conditions and techniques. Random errors can be determined, and reduced, through repeated measurements under identical conditions.
GXSPORD659	1.5.0-3	Absolute accuracy is traceable to NIST, where traceability is defined by NIST as the "property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties." (ISO VIM, 2nd. Ed., 1993, definition 6.10). This includes instituting a measurement insurance program and use of NIST practices in radiance and irradiance determinations including quality programs detailing measurement procedures and reproducibility and using trained personnel.
GXSPORD22	1.5.0-4	All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the GXS PORD, GXS UIID, and the GIRD.
GXSPORD23	1.5.0-5	Band: A set of channels.
GXSPORD24	1.5.0-6	Channel: A measurement that is an aggregate of one or more spectral samples that meets or exceeds GXS requirements.
GXSPORD25	1.5.0-7	Derived Noise Equivalent Delta Radiance (NEdN): Refers to the NEdN required to meet the NEdN specification, or the Signal-to-Noise Ratio (SNR) specification.
GXSPORD26	1.5.0-8	Detector sample or element: Digitized output from a single detector element.
GXSPORD27	1.5.0-9	Eclipse: Defined as when the solar disk is completely occulted by the Earth or Moon, as viewed from the GeoXO satellite.

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GXSPORD1336	1.5.0-10	Fixed-Grid Angles: Refers to North/South (NS) and East/West (EW) Euler angles defined as follows. Starting with the orbit reference frame (ORF) in GIRD62 at the ideal satellite location, a positive NS angle is a rotation of the ORF about its +x axis, and a positive EW angle is a subsequent rotation of the rotated frame about its +y axis. The +z axis of the final frame is the line of sight (LOS) represented by the EW and NS fixed-grid angles.
GXSPORD28	1.5.0-11	Frame: Collection of pixels from a contiguous region as commanded by a minimum bounding rectangle or one of the predefined regions such as Superregional, 62 degree LZA Disk, etc.
GXSPORD29	1.5.0-12	Fourier Transform Spectrometer (FTS) System: One approach to spectroscopy that, in contrast to a Grating System, relies on time-domain interference measurements that are converted into spectral data using a Fourier Transform.
GXSPORD30	1.5.0-13	Full Disk: Defined as a 17.4 degree diameter circle centered at nadir.
GXSPORD31	1.5.0-14	Fully Functional Configuration: Being able to perform the following functions: scene radiance measurement; radiometric calibration; star sensing; on-orbit monitoring of calibration sources and instrument response changes; acquisition of sensor health and status data; generation of the following data streams: sensor, calibration, monitoring, health and status; and reception and execution of command and control data.
GXSPORD32	1.5.0-15	Grating System: One approach to spectroscopy that, in contrast to an FTS System, relies on spectral dispersion by means of an optical grating.
GXSPORD33	1.5.0-16	Launch: The time between lift off and the separation of the GeoXO satellite from the launch vehicle.
GXSPORD1330	1.5.0-17	Level 0 data: Raw data reconstructed to unprocessed instrument data at full space-time resolution with all available supplemental information to be used in subsequent processing (e.g., ephemeris, health and safety) appended.
GXSPORD1331	1.5.0-18	Level 1a data: Unpacked, reformatted, and resampled Level 0 data with all supplemental information to be used in subsequent processing appended. Data generally presented as full space/time resolution. A wide variety of sub-level products are possible.
GXSPORD1332	1.5.0-19	Level 1b data: Unpacked, reformatted, and resampled Level 0 data with all supplemental information to be used in subsequent processing appended. Radiometric and geometric correction applied to produce parameters in physical units. Data generally presented as full space/time resolution. (This is identical to the earth-referenced instrument data with radiometric calibration applied and all calibration data appended).
GXSPORD1333	1.5.0-20	Level 2+ data: Retrieved environmental variables (e.g., sea surface temperature) and higher products.
GXSPORD34	1.5.0-21	Mesoscale: Defined as the equivalent of a 1000 km x 1000 km nadir-viewed area.

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GXSPORD1337	1.5.0-22	Mission Allowable Temperatures (MAT): Mission Allowable Temperatures are the established range of temperatures that instrument units are permitted to experience while operating in orbit. MAT are established based upon analytical temperature predictions with appropriate margin based on the state of the thermal design. MAT encompasses worst-case operating temperature predictions, uncertainty, and any vendor desired temperature margin.
GXSPORD35	1.5.0-23	Navigation: Refers to the determination of the location of each pixel relative to a fixed reference, namely for the GXS, the GRS80 geoid viewed from the idealized geostationary position, with latitude and longitude information appended in the L1b product.
GXSPORD1338	1.5.0-24	Non-operational Temperatures (NOT): Non-operational Temperatures are the established range of temperatures that instrument units are permitted to experience while not operating and not powered. NOT represent the permissible range while the hardware is powered off. Survival heaters maintain hardware at or above the cold NOT limits and passive design maintains hardware below the upper NOT limits. NOT are also known as non-operating MAT.
GXSPORD36	1.5.0-25	Pixel: All spectral channels associated with a given spatial resolution element after processing, including calibration and navigation. (Level 1b)
GXSPORD37	1.5.0-26	Precision: Refers to the standard deviation of a statistically meaningful number of samples of a measurement.
GXSPORD38	1.5.0-27	Registration: Refers to maintaining the spatial relationship between pixels within frames, between frames, and between channels.
GXSPORD39	1.5.0-28	Sounding Disk (SD): Defined as a collection of spatial resolution elements viewing the earth where the local zenith angle (LZA) to a GOES satellite is less than 62 degrees and the local zenith angle is less than or equal to the local zenith angle to the neighboring GOES satellite.
GXSPORD40	1.5.0-29	Spectral Sample: A measurement within a channel that may or may not be aggregated for transmission to the ground.
GXSPORD41	1.5.0-30	Superregional: Defined as the equivalent of a 5000 km East/West x 3000 km North/South nadir-viewed area.
GXSPORD42	1.5.0-31	Swath: Refers to any set of detector samples that are collected during a continuous scan or stepping of the detectors over the scene, in a horizontal fashion, which covers the entire horizontal extent of the scene.
GXSPORD43	1.5.0-32	Task: Repeating data collection pattern providing coverage of one or more observing regions.
GXSPORD44	1.5.0-33	Threshold Channel: A channel with the GXS required spectral resolution element width.
GXSPORD45	1.5.0-34	Unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronics unit and sensor unit.

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GXSPORD46	2	**2 Documents**
GXSPORD47	2.1	**2.1 Applicable Documents**
GXSPORD49	2.1.0-1	A New Distortion Measure for Video Coding Blocking Artifacts. Wu, H. R., Proceedings from the 1996 International Conference on Communication Technology. Volume 2, May 5-7, 1996, Beijing, China. pp 658-651. CCSDS Recommendation for Space Data System Standards, Image Data Compression, CCSDS 122.0-B-2, September 2017. General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects, Document Number GSFC-STD-7000B, April 28, 2021. General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document Number MIL-A-83577B, February 1, 1988. Geostationary Extended Observations (GeoXO) Sounding Radiances Upwelling, 418-XO-RPT-0093. Geostationary Extended Observations (GeoXO) General Interface Requirements Document (GIRD), 418-XO-GIRD-0041. Geostationary Extended Observations (GeoXO) hyperspectral radiometric Sounder (GXS) Unique Instrument Interface Document (UIID), 418-XO-GXSUIID-0030. Lossless Multispectral and Hyperspectral Image Compression, Document Number CCSDS 120.2-G-1. Low-complexity Lossless and Near-Lossless Multispectral and Hyperspectral Image Compression, Document Number CCSDS 123.0-B-2. Space Mechanisms Handbook, Document Number NASA TP-1999-206988. Space Systems Command Manual, SSCMAN 91-710, Vol 3, Range Safety User Requirements Manual – Launch Vehicles, Payloads, and Ground Support Systems Requirements. Spectral Preprocessing Transform for Multispectral and Hyperspectral Imager Compression, Document Number CCDS 122.1-B-1. Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001B, August 6, 2014. Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522A.
GXSPORD50	2.1.0-2	Fracture Control Requirements Spaceflight Hardware, NASA-STD-5019A w/Change 3. Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments, MSFC-STD-3029. NASA Payload Safety Requirements NASA-STD-8719.24A.

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GXSPORD57	2.2	**2.2 Reserved**
GXSPORD58	2.2.0-1	Reserved

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GXSPORD59	3	**3 Sensor Requirements**
GXSPORD60	3.1	**3.1 Sensor Definition**
GXSPORD61	3.1.1	**3.1.1 GXS Modes**
GXSPORD62	3.1.1.0-1	The GXS **shall** execute commands to individually enable and disable each autonomous function.
GXSPORD63	3.1.1.0-2	The GXS **shall** initiate all commanded mode transitions in no more than 20 seconds after receipt of command.
GXSPORD64	3.1.1.0-3	The GXS **shall** make limits and triggers of autonomous functions changeable by command.
GXSPORD65	3.1.1.0-4	The GXS **shall** indicate the mode of the instrument in housekeeping telemetry.
GXSPORD66	3.1.1.0-5	The GXS **shall** provide command and housekeeping telemetry functions in all powered modes.
GXSPORD67	3.1.1.1	**3.1.1.1 Safe Mode**
GXSPORD68	3.1.1.1.0-1	The GXS **shall** implement a Safe Mode.
GXSPORD69	3.1.1.1.0-2	The GXS **shall** be in a thermally and optically safe configuration for an indefinite period of time while in Safe Mode.
GXSPORD70	3.1.1.1.0-3	The GXS **shall** enter Safe Mode upon detection of internal faults capable of causing permanent damage to the instrument.
GXSPORD71	3.1.1.2	**3.1.1.2 Normal Operational Mode**
GXSPORD72	3.1.1.2.0-1	The GXS **shall** be in a fully functional configuration while in Normal Operational Mode.
GXSPORD661	3.1.1.2.0-2	The GXS **shall** meet all performance requirements while in Normal Operational Mode without receiving commands or data loads for a minimum of 7 days. *Rationale: Autonomy is required for a period of 7 days, without impacting performance.*
GXSPORD73	3.1.1.3	**3.1.1.3 Instrument Diagnostic Mode**
GXSPORD74	3.1.1.3.0-1	The GXS **shall** implement an Instrument Diagnostic Mode.
GXSPORD75	3.1.1.3.0-2	The GXS **shall** be in a fully functional configuration while in Instrument Diagnostic Mode.
GXSPORD76	3.1.1.3.0-3	The GXS **shall** by command send selected channels while in Instrument Diagnostic Mode.
GXSPORD77	3.1.1.3.0-4	The GXS **shall** by command send the individual measurement in those cases where TDI data is digitally processed off the focal plane while in Instrument Diagnostic Mode.

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GXSPORD78	3.1.1.3.0-5	The GXS **shall** by command send data from all detectors while in Instrument Diagnostic Mode.
GXSPORD79	3.1.1.3.0-6	The GXS **shall** by command send all bits from the A to D converter while in Instrument Diagnostic Mode.
GXSPORD80	3.1.1.3.0-7	The GXS **shall** by command perform electronic in-flight calibration while in Instrument Diagnostic Mode.
GXSPORD81	3.1.1.3.0-8	The GXS **shall** by command send dwell data (increased samples per second of a particular telemetry measurand) while in Diagnostic Mode.
GXSPORD82	3.1.1.4	**3.1.1.4 Outgassing**
GXSPORD83	3.1.1.4.0-1	The post-launch outgas period **shall** be no longer than 30 days. *Rationale: The GXS will sublimate and evaporate contaminants from hardware to prevent contamination from jeopardizing performance.*
GXSPORD84	3.1.2	**3.1.2 On orbit Operations**
GXSPORD85	3.1.2.1	**3.1.2.1 Zones of Reduced Data Quality**
GXSPORD86	3.1.2.1.1	**3.1.2.1.1 Operational Zone**
GXSPORD87	3.1.2.1.1.0-1	The GXS **shall** meet all operational sounding requirements for all pixels that are greater than 10 degrees in angular distance from the center of the uneclipsed sun. *Rationale: Measurement Precision, on-orbit calibration, and accuracy are met outside of the Zones of Reduced Data Quality.*
GXSPORD88	3.1.2.1.2	**3.1.2.1.2 Restricted Zone / Zones of Reduced Data Quality (ZRDQ)**
GXSPORD89	3.1.2.1.2.0-1	The GXS **shall** meet all sounding requirements, except as noted below concerning Measurement Precision (GXSPORD90), Radiometric Accuracy (GXSPORD91), and Image Navigation and Registration (GXSPORD1334), for all pixels between 10 degrees and 3 degrees in angular distance from the center of the uneclipsed Sun. *Rationale: There are relaxations near the sun in the Zones of Reduced Data Quality.*
GXSPORD90	3.1.2.1.2.0-2	For all pixels between 10 degrees and 3 degrees in angular distance from the center of the uneclipsed sun, the GXS **shall** meet the sounding requirements in the Measurement Precision section relaxed by a factor of two (GXSPORD162). *Rationale: Specifically the measurement precision is relaxed by a factor of 2 in the Zones of Reduced Data Quality near the sun.*
GXSPORD91	3.1.2.1.2.0-3	For all pixels between 10 degrees and 3 degrees in angular distance from the center of the uneclipsed sun, the GXS **shall** have an absolute calibration accuracy of either less than 2.0 K or less than the derived NEdT, whichever is greater. *Rationale: Specifically the calibration accuracy is relaxed to 2.0 K in the Zones of Reduced Data Quality near the sun.*

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GXSPORD1334	3.1.2.1.2.0-4	For all pixels between 10 degrees and 3 degrees in angular distance from the center of the uneclipsed sun, the GXS **shall** meet the sounding requirements in the Image Navigation and Registration section relaxed by a factor of 1.5 (GXSPORD210, GXSPORD214, and GXSPORD217 only). *Rationale: Specifically, the Image Navigation and Registration are relaxed by a factor of 1.5 in the Zones of Reduced Data Quality near the sun.*
GXSPORD92	3.1.2.2	**3.1.2.2 Scanning Across the Sun**
GXSPORD93	3.1.2.2.0-1	The GXS **shall** survive the presence of the sun within the field of regard without sustaining any permanent degradation in performance. *Rationale: The sun must not result in damage to the instrument.*
GXSPORD94	3.1.2.3	**3.1.2.3 Eclipse**
GXSPORD95	3.1.2.3.0-1	During eclipse periods, the GXS **shall** meet all requirements, except the four-hour phased relaxation specified in the Image Navigation and Registration (INR) section. *Rationale: Any loss of power from the solar arrays and conversion to battery power for the Spacecraft **shall** not adversely impact the instrument performance.*
GXSPORD96	3.1.2.4	**3.1.2.4 Operations after Maneuvers**
GXSPORD97	3.1.2.4.1	**3.1.2.4.1 Yaw Flip**
GXSPORD98	3.1.2.4.1.0-1	The GXS **shall** meet all requirements within 30 minutes after the spacecraft interface has returned to being within specification following a yaw flip. *Rationale: If the spacecraft executes a yaw flip, the instrument recovery will occur in this duration after the interface is restored to nominal conditions.*
GXSPORD99	3.1.2.4.2	**3.1.2.4.2 Other Maneuvers**
GXSPORD100	3.1.2.4.2.0-1	With the exception of a yaw flip, the GXS **shall** meet all radiometric, coverage and INR requirements within 2 minutes after the spacecraft interface has returned to being within specification following spacecraft maneuvers. *Rationale: If the spacecraft executes a different maneuver than a yaw flip, the instrument recovery will occur in this short duration after the interface is restored to nominal conditions.*
GXSPORD101	3.1.2.4.3	**3.1.2.4.3 Post Storage Activation**
GXSPORD102	3.1.2.4.3.0-1	The GXS **shall** meet all requirements within 5 days of GXS turn-on after post storage activation. *Rationale: After activation, GXS will cool for operations in this time listed here.*
GXSPORD103	3.1.2.4.4	**3.1.2.4.4 Detector Set-Point Temperature**

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GXSPORD104	3.1.2.4.4.0-1	The GXS detector set-point temperature **shall** be selectable by command near the nominal temperature to ensure radiometric performance during degradation and at end of life. *Rationale: This provides for set point temperature adjustments that may be needed due to aging or troubleshooting.*
GXSPORD105	3.1.2.4.4.0-2	The GXS detector temperatures **shall** be included in telemetry to support radiometric performance. *Rationale: GXS will be thermally sensitive due to its detectors and thermal telemetry will provide information for potential corrections and troubleshooting.*
GXSPORD106	3.2	**3.2 Normal Operational Mode Sensor Requirements**
GXSPORD107	3.2.1	**3.2.1 Spectral Requirements**
GXSPORD108	3.2.1.0-1	GXS **shall** provide the spectral range as specified in the wavelength or wavenumber column in the Sounding Spectral Range Table below.

Sounding Spectral Range Table

Band	Wavenumber (cm^{-1})	Wavelength (μm)
LWIR region (temperature, LWIR window, ozone, NH_3, isoprene, HNO_3, low level moisture)	680 - 1095	14.7 – 9.13
MWIR region (vertical moisture, window and temperature, N_20 and CO)	1689 – 2250	5.92 – 4.44

Rationale: Spectral ranges for GXS provide data for temperature and moisture profiles of the earth's atmosphere. These bands overlap with the European MTG-IRS instrument that will provide valuable test data to NOAA for future algorithm validation.

ID	Object Number	Text
GXSPORD109	3.2.1.1	**3.2.1.1 Spectral Resolution**
GXSPORD110	3.2.1.1.0-1	The GXS sounding channels **shall** have a maximum width as specified in the Maximum Width for Sounding Channels Table below, where the full-width-half-maximum (FWHM) of the instrument line-shape function (ILS) of the Level 1b product is used for filter or grating implementations, or the width from peak to the first zero crossing of the unapodized line-shape function (ideally a Sinc function) is used for an FTS implementation (i.e., 1/(2*max optical path difference)).

Maximum Width for Sounding Channels Table

Spectral Range	Wavenumber (cm^{-1})

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GXSPORD110 3.2.1.1.0-1

680- 1095 (cm^{-1}) 14.7 – 9.13 (μm)	0.625
1689 – 2250 (cm^{-1}) 5.92 – 4.44 (μm)	0.625

Rationale: Spectral resolution reflects that of the CO_2 features that provide vertical temperature information. Water vapor band resolution matches that of the European MTG-IRS instrument that will provide valuable test data to NOAA for future algorithm validation. Note that this specification is dictated by retrieval performance and is intended to be agnostic of spectrometer type.

GXSPORD111 3.2.1.2

3.2.1.2 Spectral Response

GXSPORD112 3.2.1.2.0-1

Reference spectral response functions **shall** be provided.

Rationale: Physical retrievals of temperature and moisture profiles are dependent on the spectral response function, after correction across the instrument FPA.

GXSPORD113 3.2.1.3

3.2.1.3 Spectral Purity

GXSPORD114 3.2.1.3.0-1

Differences between the corrected spectral response functions across the FPAs and the nominal on-axis reference spectral response **shall** be less than the NEdN over the operational life of the sensor.

Rationale: Corrected here refers to the measured spectral response after application of a correction methodology that accounts for items such as instrument off-axis effects and instrument alignment changes over time. On-axis spectral response refers to the spectral response on the optical axis of the instrument.

GXSPORD115 3.2.1.4

3.2.1.4 Spectral Knowledge, Uniformity, and Stability

GXSPORD116 3.2.1.4.0-1

With channel center knowledge provided by the GeoXO System of at least one channel in the 9.13 μm to 14.7 μm spectral region and one channel in the 4.44 μm to 5.92 μm spectral region, for 50% of the detector IFOV's in the sensor, and with updates occurring at the minimum of once per hour, the GXS channel center stability **shall** be within 5 ppm of channel wavelength over any 24 hour period.

Rationale: Reflects likely spectral calibration method provided by ground processing in order to achieve GXS channel center stability.

GXSPORD679 3.2.1.4.0-2

The GXS sounding channels for any given pixel **shall** have the same center frequencies as any other pixel.

Rationale: Constant channel center information is critical to ingest for numerical weather prediction. Spectral resampling may be used to meet this requirement; if so, all other relevant performance requirements apply to the resampled data product.

GXSPORD117 3.2.1.5

3.2.1.5 Spectral Region Breaks

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD118	3.2.1.5.0-1	With the exception of permissible inoperable channels, the GXS spectral coverage **shall** be continuous for the required spectral range except for one allowable missing span per region less than the "maximum size of break" column and not contained in the "excluded region for region break" column in the following table.

Spectral Region Breaks

Region	Excluded span for region break (µm)	Maximum size of break (µm)
680- 1095 (cm^{-1}) 14.7 – 11.20 (µm)	13.4 – 13.95	0.12
1689 – 2150 (cm^{-1}) 5.92 – 4.65 (µm)	None	0.05
2150 – 2250 (cm^{-1}) 4.65 – 4.44 (µm)	4.65 – 4.44	0.050

Note that these regions intentionally do not correspond exactly with the spectral bands defined above.

Rationale: Spectral band breaks are not permitted in key spectral regions.

GXSPORD119 3.2.2

3.2.2 Scan Requirements

GXSPORD120 3.2.2.1

3.2.2.1 Coverage Rate

GXSPORD121 3.2.2.1.0-1 Note that these coverage requirements define a capability and not a definitive operational scenario. Rather, NOAA anticipates operating GXS in an asynchronous manner that uses information from other instruments and models to identify potential regions for scanning/stepping by GXS. To perform its tasks, commanding of GXS for these targeted observations will be based on priorities and availability.

GXSPORD122 3.2.2.1.0-2 In Disk Sounding task, the GXS **shall** acquire each Sounding Disk (SD) and perform all necessary housekeeping and calibration functions in less than 60 minutes.

Rationale: When covering the 62-degree LZA region, the coverage including all calibrations will take 60 minutes or less to ensure a timely coverage rate for the instrument that may be used to cover either smaller areas in proportionally smaller times or larger areas in proportionally longer times.

GXSPORD123 3.2.2.1.0-3 The GXS **shall** be commandable into custom tasks with regions interspersed in any order, including within other acquisitions, in order to collect individual sounding coverage areas (e.g. super-regional, mesoscale, or any other shape). An example of potential operations is shown in the table below. This capability should reflect the coverage rate above, based on area-per-time calculation.

Example of Potential Operations (For Reference Only)

Example of a potential multi-regional sounding task for operations

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD123	3.2.2.1.0-3	

Region	Revisit Time
SD	120 min
Super-regional (3000 km x 5000 km)	60 min
Mesoscale (1000 km x 1000 km)	7 min

Rationale: The GXS must be commandable to cover regions of interest. Regions will be covered with the same instrument coverage rate as SD in 60 minutes. Adding multiple regions will reduce refresh for the SD and coverage times for Full Disk, Superregional, mesoscale, or other areas will essentially scale with coverage area for these other regions.

GXSPORD1335 3.2.2.1.0-4

The GXS **shall** upload command observations of clear-sky-masked regions, using the remaining time from not observing cloudy regions in the anchor case to observe additional mesoscale regions.

Rationale: An anchor case is the nominally planned observations for the anchor case period (i.e., SD in 60 minutes or 0.9 northern half of SD plus 2 mesos in 30 min). Bonus time from not observing clouds in the anchor case period will be converted to an integer number of mesoscale observing times plus idle residual time, where locations of mesoscale observations are determined by ground operations.*

GXSPORD124 3.2.2.2

3.2.2.2 Scan/Step Direction

GXSPORD125 3.2.2.2.0-1

The dominant direction of instrument data collection **shall** be in the West-East directions.

Rationale: Weather moves from West to East in CONUS.

GXSPORD126 3.2.2.2.0-2

To accommodate a possible seasonal yaw flip, data collection **shall** be possible in West to East, and East to West directions.

Rationale: Weather moves from West to East so need to address this after yaw flip as well.

GXSPORD127 3.2.2.2.0-3

To accommodate a possible seasonal yaw flip, stepping **shall** be possible in North to South, and South to North directions.

Rationale: After yaw flip, North and South flip relative to instrument axes.

GXSPORD128 3.2.2.2.0-4

Ground sample data acquisition should begin with the northernmost coordinate and proceed south.

Rationale: This reflects current observations and conventions.

GXSPORD129 3.2.2.3

3.2.2.3 Flexible and Selectable Scan Pattern

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD130	3.2.2.3.0-1	The GXS sensor **shall** scan an area of arbitrary size anywhere within the field of regard when commanded, including Superregional and Mesoscale regions. *Rationale: Permits flexible tasking of GXS to regions of interest, likely including Superregional and Mesoscale.*
GXSPORD131	3.2.2.3.0-2	The scan area and geographic location **shall** be selectable from one frame to the next. *Rationale: Permits flexible tasking of GXS to regions of interest, likely including Superregional and Mesoscale.*
GXSPORD132	3.2.2.3.0-3	The GXS **shall** be designed such that the Earth-scanning patterns are fully programmable on-orbit. *Rationale: Permits flexible tasking of GXS to regions of interest, likely including Superregional and Mesoscale.*
GXSPORD133	3.2.2.4	**3.2.2.4 Scan Efficiency and Simultaneities**
GXSPORD134	3.2.2.4.0-1	For the sounding tasks, data for all the channels obtained from any specific point on the Earth **shall** be coincident within 18 seconds. *Rationale: Spectrally simultaneous observations provide observations of the same features in the atmosphere and avoid artifacts in resulting data.*
GXSPORD135	3.2.2.4.0-2	The time between collection of adjacent pixels within a single GXS data frame **shall** be less than or equal 10 minutes. *Rationale: This limits shearing in an image composed of multiple individual observations.*
GXSPORD136	3.2.2.4.0-3	The data **shall** be time identified so that the time any detector sample in the data was acquired can be determined to within 0.1 milliseconds relative to the spacecraft provided clock information. The spacecraft clock is synchronized to Universal Time (UT) to an accuracy defined in the GIRD. *Rationale: Temporal telemetry is needed to facilitate data processing.*
GXSPORD137	3.2.2.5	**3.2.2.5 Data Latency**
GXSPORD138	3.2.2.5.0-1	For sounding products, the GXS **shall** contribute to the total data latency for the Level 1b product of no more than 180 seconds for calibrated, navigated radiances. Data latency is measured from the time the instrument collects all samples for an earth scene (or frame) to the time the data is available for dissemination on the ground as Level 1b data. The GXS contribution to data latency includes delay of delivery of data to the spacecraft and delay due to ground algorithm processing (i.e., any resampling and INR). *Rationale: Latency between the last observation of the input data to the Level 1b processing and the availability of the data for further processing should be as short as practical.*

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD140	3.2.3	**3.2.3 Spatial Sampling Requirements**
GXSPORD141	3.2.3.1	**3.2.3.1 Field of Regard**
GXSPORD142	3.2.3.1.0-1	The unvignetted Field of Regard (FOR) of the instrument **shall** include a circle of at least 20 degrees in diameter with its center at the sub-satellite point and accounting for alignment errors as described in the GIRD. *Rationale: A boresighted, clear FOR of 20 degrees affords sufficient star coverage in the annulus around the edge of the earth and the edge of the FOV to permit acceptable navigation, and also supports observations of the moon which is an important calibration reference source.*
GXSPORD143	3.2.3.2	**3.2.3.2 Ground Sample Distance and Angle**
GXSPORD144	3.2.3.2.0-1	The centroid-to-centroid distance between adjacent spatial samples on the Earth's surface, as measured at the Sub-Satellite Point, defines the ground sample distance (GSD). The ground sample angle (GSA) is the associated angle. A two-dimensional pixel is defined by the GSD in the East/West and North/South dimensions. The GXS **shall** have a GSA no larger than 112 microradians (4 km at nadir) for emissive channels. *Rationale: GSA defines the spatial sampling for the Level 1b output of GXS.*
GXSPORD146	3.2.3.3	**3.2.3.3 Detector Sample Ground Footprint**
GXSPORD148	3.2.3.3.1	**3.2.3.3.1 Dynamic Ensquared Energy**
GXSPORD149	3.2.3.3.1.0-1	The dynamic ensquared energy (EE) is a unitless figure of merit that is defined as an energy ratio. The energy ratio's numerator is the energy measured by a nominal pixel of 112 μrad x 112 μrad, from a projection of the nominal pixel onto the sample area of a uniform scene from an infinite plane. The energy ratio's denominator is the energy measured by the nominal pixel from the extent of the full uniform scene from an infinite plane. The EE can be understood in terms of the scene spread function (SSF), which is the convolution of the polychromatic system point spread function (PSF) with the nominal pixel spatial response function (SRF) including, but not limited to, any jitter, scan effects, optical crosstalk, and electrical crosstalk. As a standard, the EE is always referenced to a nominal pixel of 112 μrad x 112 μrad. The EE requirements are presented by band. The requirement applies to all channels within each specified band. The GXS EE **shall** be greater than or equal to 70% for the aggregate of the channels within each band as defined in the Sounding Spectral Range Table.
GXSPORD152	3.2.3.4	**3.2.3.4 Co-Registration**
GXSPORD153	3.2.3.4.0-1	Between emissive channels, the channel-to-channel registration, or co-registration, is defined as the following correlation equation:

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GXSPORD153 3.2.3.4.0-1

$$R_{ij} = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} SSF_i(x,y)SSF_j(x,y)dxdy}{\sqrt{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} SSF_i(x,y)SSF_i(x,y)dxdy}\sqrt{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} SSF_j(x,y)SSF_j(x,y)dxdy}}$$

Where : $SSF_i(x, y)$ is the navigated scene spread function of channel i.

The co-registration between emissive channels within the same band (LWIR or MWIR) **shall** be greater than 95%.

Rationale: Co-registration needs to be very high to ensure that the same phenomena are being observed for all bands.

GXSPORD154 3.2.3.4.0-2 The co-registration between emissive channels from different bands **shall** be greater than 80%.

GXSPORD156 3.2.4

3.2.4 Radiometric Performance Requirements

GXSPORD157 3.2.4.1

3.2.4.1 Dynamic Range

GXSPORD158 3.2.4.1.0-1 The sounding spectral regions **shall** have sufficient dynamic range to measure cold space and the peak temperature for any one channel (as specified in the Dynamic Range and Precision Table) and the integrated flux for the band (as specified in the Dynamic Range and Precision Table).

Rationale: Both cold space and the earth scene need to be observed, along with a reference blackbody in order to provide sufficiently calibrated data.

GXSPORD161 3.2.4.2

3.2.4.2 Measurement Precision (NEdN and NEdT)

GXSPORD162 3.2.4.2.0-1 For the corresponding black body scene and for linear interpolation in the corresponding dimensions for regions with multiple points specified, the GXS sounder **shall** have a maximum Noise Equivalent Delta Radiance as specified in the Dynamic Range and Precision Table.

Notes:

1. This specification applies equally to individual channel observations and to Fourier transformed channel observations.
2. Per industry standard, the noise equivalent temperature error is reported as the error when viewing a 250K scene; however, the actual scene is not necessarily a 250K scene.
3. For data acquired at more than one sample per channel, the noise performance for terms that are uncorrelated between channels can be reduced by a factor of the inverse of the square root of the oversampling.
4. For each spectral channel, NEdN = dB/dT *NEdT, where dB/dT is the derivative of the blackbody function at 250 K for that spectral channel, and NEdT is the Noise Equivalent Delta Temperature.

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GXSPORD162 3.2.4.2.0-1

Dynamic Range and Precision Table

Spectral Range	Max BB Temp for any one channel	Max BB Temp for integrated flux in range	NEdN mW/(m^2 sr cm^{-1})
680-718 cm^{-1} 13.9-14.7 μm	306 K	287 K	2.5 at 680 cm^{-1} and 0.352 at 718 cm^{-1} interpolated in wavenumber for 224K scene
718-800 cm^{-1} 12.5-13.9 μm	306 K	287 K	0.352 for 224K scene
800-881 cm^{-1} 11.34-12.5 μm	306 K	304.5 K	0.2 for 234 K scene
881-1095 cm^{-1} 9.13-11.34 μm	306 K	297 K	0.2 for 218 K scene
1689-2150 cm^{-1} 4.65-5.92 μm	306 K	270 K	0.06 for 234 K scene
2150 - 2250 cm^{-1} 4.44-4.65 μm	304 K	273 K	0.06 for 228 K scene

GXSPORD163 3.2.4.2.1

3.2.4.2.1 Pixel Operability

GXSPORD164 3.2.4.2.1.0-1

Neglecting missing spectral channels resulting from permissible band breaks, the number of channels meeting the noise requirements associated with the Dynamic Range and Precision Table **shall** be at least 50% for grating systems with the distribution of failing channels being less than the percentages in the "Inoperability per Region" column in the following table and with contiguous failing channels being less than the "Maximum Cluster Length" column in the 1x Channel Inoperability for Grating Table below.

1x Channel Inoperability for Grating Table

Spectral Range	Maximum Cluster Length	Inoperability per Region
12.5 - 14.7 μm	5	50%
11.34 - 12.5 μm	5	50%
9.13 – 11.34 μm	5	50%
4.65 – 5.92 μm	5	50%
4.44 – 4.65 μm	5	50%

GXSPORD165 3.2.4.2.1.0-2

Neglecting missing spectral channels resulting from permissible band breaks, the number of channels meeting 2x the noise requirements associated with the Dynamic Range and Precision Table **shall** be at least 84% for grating systems with the distribution of failing channels being less than the percentages in the "Inoperability per Region" column in the following table and with contiguous failing channels being

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GXSPORD165 3.2.4.2.1.0-2 less than the "Maximum Cluster Length" column in the 2x Channel Inoperability for Grating Table below.

Rationale: For grating systems, individual pixel outage is permitted to avoid driving detector quality.

2x Channel Inoperability for Grating Table

Spectral Range	Maximum Cluster Length	Inoperability per Region
12.5 - 14.7 µm	5	16%
11.34 - 12.5 µm	5	16%
9.13 – 11.34 µm	5	16%
4.65 – 5.92 µm	5	16%
4.44 – 4.65 µm	5	16%

GXSPORD166 3.2.4.2.1.0-3 The number of pixels compliant with the 1x noise in the Dynamic Range and Precision Table above **shall** be at least 50% for an FTS system.

GXSPORD167 3.2.4.2.1.0-4 The number of pixels compliant with the 2x noise in the Dynamic Range and Precision Table **shall** be at least 84% for an FTS system.

GXSPORD168 3.2.4.2.1.0-5 For pixels failing a 2x noise requirement or inoperability per region requirement, no more than 50% of the failing pixels **shall** have a neighbor, including diagonal neighbors, which is also a failing pixel.

Rationale: For grating systems, individual pixel outage are permitted to avoid driving detector quality.

GXSPORD172 3.2.4.3

3.2.4.3 Radiometric Accuracy

GXSPORD173 3.2.4.3.1

3.2.4.3.1 Absolute Accuracy

GXSPORD174 3.2.4.3.1.0-1 The GXS absolute radiometric accuracy is the unknown bias error in the measured radiance in each spectral channel, root-sum-squared (RSS) with any random precision or repeatability component in a specific measurement period. It is specified in terms of a brightness temperature error at 300 K for emissive bands.

For all emissive channels, the GXS absolute accuracy **shall** be less than or equal to 1K or the derived NEdT, whichever is greater.

Absolute accuracy values presented are 3-sigma.

Rationale: Using the definition above, the GXS absolute accuracy is constrained to be less than 1 K or the noise level to avoid limiting impact to higher level products.

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GXSPORD175	3.2.4.3.1.0-2	All calibration **shall** be traceable to National Institute of Standards and Technology (NIST) standards. *Rationale: Calibrations **shall** follow NIST methodologies to ensure unbreakable chain for traceability.*
GXSPORD176	3.2.4.3.2	**3.2.4.3.2 Relative Accuracy**
GXSPORD177	3.2.4.3.2.0-1	The relative radiometric accuracy is defined as the unknown bias error between two arbitrary radiance measurements, root-sum-squared (RSS) with any random precision or repeatability component in a specific measurement period. The relative accuracy error is defined as the RMS variation in signal level, for all measurements in a large ensemble (e.g. all the pixels in a frame such that the residual temporal variation does not dominate the calculation,) illuminated by constant scene radiance and over expected geostationary environmental conditions and calibration frequency. All relative accuracy values presented are 1-sigma.
GXSPORD178	3.2.4.3.2.1	3.2.4.3.2.1 Scan Position to Scan Position Relative Accuracy
GXSPORD179	3.2.4.3.2.1.0-1	The difference in calibrated radiance between scan positions (where scan position refers to location of a target within a swath) for the emissive channels **shall** be less than or equal to the derived NEdN evaluated using the scan position to Scan Position to Scan Position Equation as provided and illustrated below.

Scan Position to Scan Position Equation

$$Derived\ NEdN > \sqrt{\frac{1}{N_P}\sum_{r=0}^{N_P-1}\left(\bar{I}_{r,s_0} - \bar{I}_{r,s_1}\right)^2}$$

where

r is the position (target) index.

s_0, s_1 is a scan position (target) pair, and s_0 is always the starting point for the East-West position (target) scan.

$\bar{I} = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} P_{i,j}$ is the mean of an M-by-N position (target) image where N is 2M and is in the scan direction and

N_P is the number of positions (targets) needed to state (at the 90% confidence level) that the requirement is met.

GXSPORD179 3.2.4.3.2.1.0-1

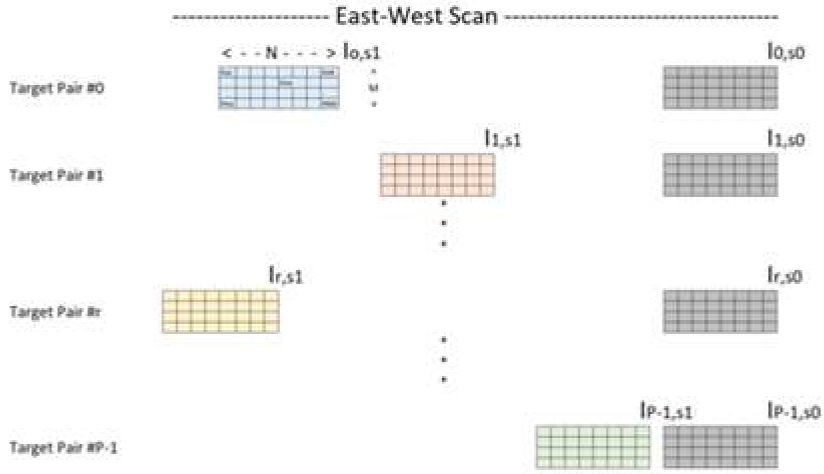

Illustration of Scan Position to Scan Position Evaluation

Rationale: Scan position to scan position relative accuracy limits detection errors as a function of scan position.

GXSPORD180 3.2.4.3.2.2

3.2.4.3.2.2 Pixel-to-Pixel Relative Accuracy

GXSPORD181 3.2.4.3.2.2.0-1

For each and every 3x10 region on the SD, the difference in radiance between calibrated detector samples for each emissive channel **shall** be less than or equal to the derived NEdN evaluated using the Pixel-to-Pixel Equation as provided and illustrated below.

Pixel-to-Pixel Equation

$$\text{Derived NEDN} > \sqrt{\frac{1}{3}\sum_{i=0}^{2}(\overline{R_i} - \overline{R})^2}$$

where

$\overline{R} = \frac{1}{30}\sum_{i=0}^{2}\sum_{j=0}^{9} P_{i,j}$ is the mean for 30 calibrated detector samples comprised of 3 rows by 10 columns.

$\overline{R}_i = \frac{1}{10}\sum_{j=0}^{9} P_{i,j}$ is the row mean over 10 calibrated detector samples for row i.

$P_{i,j}$ is the calibrated detector sample value for row i, column j

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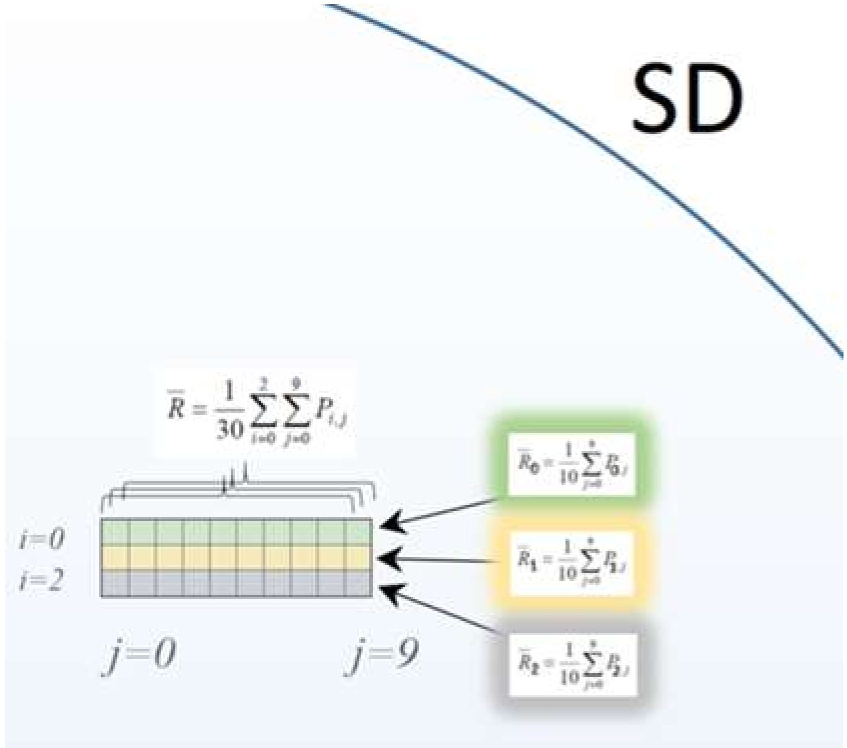
GXSPORD181	3.2.4.3.2.2.0-1	 Illustration of Pixel-to-Pixel Evaluation *Rationale: Pixel-to-pixel relative accuracy limits detection errors in nearby observing regions.*
GXSPORD182	3.2.4.3.2.3	3.2.4.3.2.3 Channel-to-Channel Relative Accuracy
GXSPORD183	3.2.4.3.2.3.0-1	The difference in calibrated radiance between emissive channels **shall** be less than or equal to the derived NEdT evaluated using the Channel-to-Channel Equation as provided and illustrated below. Channel-to-Channel Equation $Derived\ NEdT > \sqrt{\frac{\sum_{r=1}^{N_I}\left(\overline{T}_{r,c_1} - \overline{T}_{r,c_2}\right)^2}{N_I}}$ where c_1, c_2 is the emissive wavelength channel pair, $\overline{T} = \frac{\sum_{i=0}^{M}\sum_{j=0}^{N} T_{i,j}}{MN}$ is the mean brightness temperature for a Superregional frame N_I is the number of images required to state (at 90% confidence) that the requirement is met and $Derived\ NEdT$ is the largest specified Noise Equivalent Delta Temperature for the two channels.

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GXSPORD183 3.2.4.3.2.3.0-1

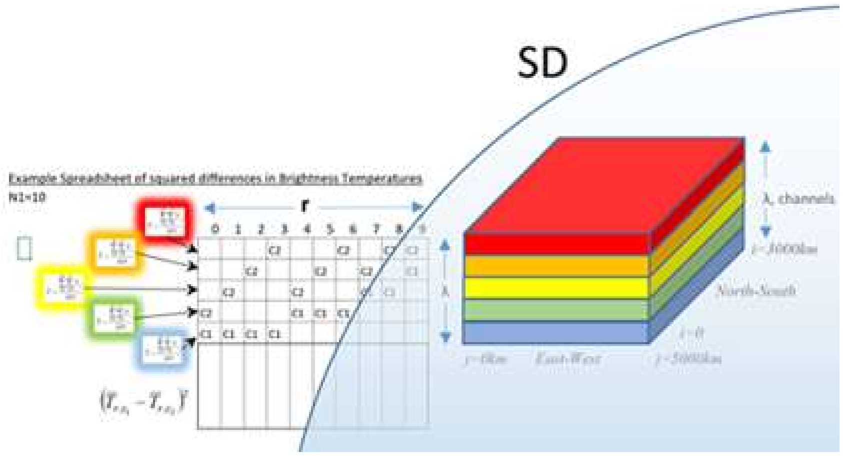

Illustration of Channel-to-Channel Relative Accuracy

Rationale: Channel-to-Channel relative accuracy limits detection errors between spectral channels.

GXSPORD184 3.2.4.3.2.4

3.2.4.3.2.4 Calibration-to-Calibration Relative Accuracy

GXSPORD185 3.2.4.3.2.4.0-1

The difference in calibrated radiance between calibrations for each emissive band **shall** be less than or equal to the derived NEdN evaluated using the Calibration-to-Calibration Relative Accuracy Equation below.

Calibration-to-Calibration Relative Accuracy Equation

$$\text{Derived NEdN} > \sqrt{\frac{1}{N_C}\sum_{r=0}^{N_C-1}\left(\bar{I}_{before}-\bar{I}_{after}\right)^2}$$

where

$$\bar{I} = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} P_{i,j}$$ is the mean of a Superregional frame and

N_C is the number of image pairs (with an intervening blackbody calibration) required to state (at the 90% confidence level) that the requirement is met.

Rationale: Calibration-to-calibration relative accuracy limits detection errors between calibrations.

GXSPORD187 3.2.4.3.3

3.2.4.3.3 On-Orbit Calibration

GXSPORD188 3.2.4.3.3.0-1

The GXS **shall** have on-board, full aperture and full system calibration for all emissive channels; i.e., the clear aperture of every component in the optical train is subject to calibration.

Rationale: Best practice for calibration of instrument.

GXSPORD197 3.2.5

3.2.5 Image Navigation and Registration

GXSPORD198 3.2.5.1

3.2.5.1 INR Scope

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD199	3.2.5.1.0-1	Image navigation refers to the determination of the location of each image pixel relative to a fixed reference coordinate system. Image registration refers to maintaining the spatial relationship between pixels within image frames and between image frames. Mission-level INR requirements apply to pixels and encompass the combined system performance of the GXS, spacecraft and ground processing system.
GXSPORD200	3.2.5.2	**3.2.5.2 INR Function**
GXSPORD201	3.2.5.2.0-1	This section defines several INR-related functions to be included in the GXS and associated GeoXO ground system.
GXSPORD202	3.2.5.2.1	**3.2.5.2.1 Star Sensing**
GXSPORD203	3.2.5.2.1.0-1	If autonomous star sensing is required to meet navigation requirements, the GXS **shall** have an on-board star catalog provided by the GXS vendor, which is loadable and modifiable from the ground and covers a span of two weeks. *Rationale: If employed, star sensing will require a star catalog and not rely on operators.*
GXSPORD205	3.2.5.3	**3.2.5.3 INR Performance Requirements**
GXSPORD206	3.2.5.3.0-1	All INR requirements listed herein apply to the end-to-end system, taking all instrument, spacecraft, and ground processing effects into account. INR errors for any given pixel(s) can be determined through analysis and simulation, while on-orbit verification will require using landmarks in an image.
GXSPORD207	3.2.5.3.0-2	Unless otherwise specified, all INR requirements in this document are specified in terms of North/South and East/West fixed-grid angles, in microradians, 3-sigma, and refer to all hours of operation. In the context of sounder INR, 3-sigma error is defined to be equal to the 99.73rd percentile of the absolute values of all INR error observations collected over each 24-hour period from local noon to local noon. When INR requirements are temporarily suspended, due to Sun/Earth geometry or maneuver outages (including recovery time), the raw errors during the requirements suspension period should be ignored.
GXSPORD208	3.2.5.3.0-3	In this section, "frame" refers to any programmed scan area data set ranging from a full disk down through the mesoscale in pixel space, as opposed to detector sample space.
GXSPORD209	3.2.5.3.1	**3.2.5.3.1 Navigation**
GXSPORD210	3.2.5.3.1.0-1	Navigation error is the angular location knowledge error of pixels or features in a frame. For emissive channels, the navigation error **shall** not exceed 42 microradians for pixels on the Earth's disk, except during eclipse periods.
GXSPORD212	3.2.5.3.1.0-2	For up to a four-hour period that includes an eclipse of the Sun, the GXS navigation error **shall** not exceed 64 microradians for emissive channels. The phasing of the four-hour relaxation relative to the eclipse may be design-specific and will be recommended by the GXS contractor.
GXSPORD213	3.2.5.3.2	**3.2.5.3.2 Frame-to-Frame Registration**

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD214	3.2.5.3.2.0-1	Frame-to-frame registration error is the difference in navigation error for any given pixel in two consecutive frames. "Any given pixel in two consecutive frames" refers to the nearest pixel to any given Earth-fixed location in two consecutive frames. Since frames may be 60 minutes apart, these requirements apply over 60 minute periods. For emissive channels, frame-to-frame registration errors **shall** not exceed 35 microradians.
GXSPORD216	3.2.5.3.3	**3.2.5.3.3 Within-Frame Registration**
GXSPORD217	3.2.5.3.3.0-1	Within-frame registration error is the difference between the estimated and nominal distance between any two pixels in a frame. "Estimated distance" refers to the distance between the navigated pixel locations as reported in the Level 1b data. "Nominal distance" refers to the distance between the actual locations of the scene elements sampled by the pixels. For emissive channels, the within-frame registration error **shall** not exceed 42 microradians.
GXSPORD219	3.2.6	**3.2.6 Data Compression**
GXSPORD220	3.2.6.0-1	The GXS may perform lossy data compression in order to satisfy the GXS requirements.
GXSPORD221	3.2.6.0-2	If performed, lossy compression **shall** not prevent the GXS from meeting requirements. *Rationale: Constraint on application is not to degrade data beyond performance levels.*
GXSPORD222	3.2.6.0-3	Command activation of lossy compression capability **shall** be on a channel-by-channel basis.
GXSPORD223	3.2.6.0-4	All calibration data **shall** be lossless compressed or uncompressed. *Rationale: Calibration data needs to be a high quality so nominally it should not be compressed as it may impact performance.*

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GXSPORD1000	4	**4 Design Requirements**
GXSPORD1001	4.1	**4.1 Reliability**
GXSPORD1002	4.1.0-1	The GXS **shall** demonstrate by analysis a Reliability (R) of at least 0.6 after 10 years of on-orbit operations, preceded by ground storage, and up to 5 years of on-orbit storage. *Rationale: The design life of at least 10 years extends from commencement of on-orbit operations until Reliability falls to 0.6.*
GXSPORD1003	4.1.0-2	The GXS **shall** demonstrate by analysis a Mean Mission Duration (MMD) of at least 8.4 years by integrating under the Reliability curve for 10 years of on-orbit operations, preceded by the storage periods.
GXSPORD1004	4.1.0-3	No credible single-point failure in GXS flight heater components **shall** permanently preclude the Instrument from supporting the mission.
GXSPORD1005	4.1.0-4	No credible single-point failure in GXS flight temperature-sensing components **shall** permanently preclude the Instrument from supporting the mission.
GXSPORD1006	4.1.0-5	To satisfy the Reliability and Design Life Requirements, the Instrument may choose selectively redundant approaches beyond those explicitly required in GXSPORD1004 and GXSPORD1005.
GXSPORD1007	4.1.0-6	The GXS **shall** withstand without damage the sudden removal of operational power.
GXSPORD1008	4.2	**4.2 Redundancy**
GXSPORD1009	4.2.1	**4.2.1 Redundant Component Selectabiltiy**
GXSPORD1010	4.2.1.0-1	The GXS redundant components **shall** be selectable by external command only.
GXSPORD1011	4.2.2	**4.2.2 Interchangability of Flight Model Units**
GXSPORD1012	4.2.2.0-1	The GXS units of any Flight Model (FM) **shall** be interchangeable, without modification, with the equivalent units of any other FM.
GXSPORD1013	4.2.3	**4.2.3 Cryocooler Operation**
GXSPORD1014	4.2.3.0-1	Reserved
GXSPORD1015	4.3	**4.3 Mechanical Requirements**
GXSPORD1016	4.3.0-1	Compliance with the requirements in this section ensures that the GXS unit structures possess sufficient strength, rigidity, and other characteristics required to survive the critical loading conditions that are expected during the GeoXO mission.
GXSPORD1017	4.3.0-2	All threaded fasteners **shall** employ a locking feature.
GXSPORD1018	4.3.1	**4.3.1 Design Limit Loads**

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GXSPORD1019	4.3.1.0-1	Limit loads are defined as all worst-case load conditions enveloping temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch, on-orbit operations, and storage.
GXSPORD1020	4.3.1.0-2	The GXS Instrument units not mounted on the spacecraft nadir deck **shall** survive a limit static positive and negative acceleration load applied at the spacecraft interface in each axis individually to the values shown in the Mass Acceleration Table and Mass Acceleration Curve in GIRD385, multiplied by the Static load factors from the GeoXO Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads Table listed in GXSPORD1024.
GXSPORD1021	4.3.1.0-3	The GXS Instrument units mounted on the spacecraft nadir deck **shall** survive a limit static positive and negative acceleration load applied at the spacecraft interface in each axis individually to the values shown in the Table GIRD387 Nadir Deck Mass Acceleration multiplied by the Static load factors from the GeoXO Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads Table listed in GXSPORD1024.
GXSPORD1022	4.3.2	**4.3.2 Yield Strength**
GXSPORD1023	4.3.2.0-1	The GXS structures **shall** support yield loads without detrimental permanent deformation with load factors from the Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads Table listed in GXSPORD1024.

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GXSPORD1024	4.3.2.0-2	GeoXO Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads[1,2] Table

Type	Static	Sine	Random/Acoustic[4,5]
Metallic-Yield	1.25[3]	1.25	1.6
Metallic Ultimate	1.4[3]	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
Composite/Glass Ultimate	1.5	1.5	1.9
Bonded Inserts/Joints Ultimate	1.5	1.5	1.9

1 - Factors of safety for pressurized systems to be compliant with SSCMAN 91-710 Vol, Section 12.4.2.1.

2 - Factors of safety for pressurized bonded glass and glass joints specified in NASA-STD-5001.

3 - If qualified by analysis only, positive margin must be shown for factors of safety of 2.0 on yield and 2.6 on ultimate. Project approval required for analysis only.

4 - Factors shown should be applied to statistically derived peak response based on RMS level.

5 - Factors shown assume that qualification/protoflight testing is performed at acceptance level plus 3dB. If difference between acceptance and qualification levels is less than 3dB, then above factors may be applied to qualification level minus 3dB instead of analyzing to acceptance level.

GXSPORD1339 4.3.2.0-3 As a minimum, the peak response for Random/Acoustic loads listed in GXSPORD1024 **shall** be calculated as a 3-sigma value.

GXSPORD1025 4.3.3

4.3.3 Ultimate Strength

GXSPORD1026 4.3.3.0-1 The GXS structures **shall** support ultimate loads without collapse or rupture when subjected to loads with the applied ultimate load factors from the GeoXO Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads Table listed in GXSPORD1024.

GXSPORD1027 4.3.4

4.3.4 Unit Stiffness

GXSPORD1028 4.3.4.0-1 The fundamental resonant frequency of the GXS Sensor Unit **shall** be 45 Hz or greater when the sensor unit is rigidly constrained at its spacecraft interface and the sensor unit is in its launch configuration. The fundamental resonant frequency is defined as the lowest mode with more than 2% effective modal mass in any direction.

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GXSPORD1029	4.3.4.0-2	The fundamental resonant frequency of the GXS Electronics Unit(s) **shall** be 50 Hz or greater when the electronics units are rigidly constrained at their spacecraft interfaces. The fundamental resonant frequency is defined as the lowest mode with more than 2% effective modal mass in any direction.
GXSPORD1030	4.3.4.0-3	The GXS units **shall** survive the Instrument-level random and sine vibration testing with notching of interface forces to design limits only.
GXSPORD1031	4.3.5	**4.3.5 Critical Members Design Values**
GXSPORD1032	4.3.5.0-1	For critical members, design values **shall** be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence. Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units.
GXSPORD1033	4.3.6	**4.3.6 Redundant Members Design Values**
GXSPORD1034	4.3.6.0-1	For redundant members, design values **shall** be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence. Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity.
GXSPORD1035	4.3.7	**4.3.7 Selective Design Values**
GXSPORD1036	4.3.7.0-1	As an exception to GXSPORD1032 and GXSPORD1034, greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.
GXSPORD1037	4.3.8	**4.3.8 Fracture Control**
GXSPORD1038	4.3.8.0-1	The GXS shall comply with the fracture control requirements for the following elements in compliance with NASA-STD-5019A-C3 w/Change 3: a) Pressure vessels, dewars, lines, and fittings b) Castings unless hot isostatically pressed and the flight article is proof tested to 1.25 times limit load c) Weldments d) Parts made of materials not in Table I of MSFC-STD-3029, if under sustained tensile stress e) Parts made of materials susceptible to cracking during quenching f) Nonredundant, mission-critical preloaded springs loaded to greater than 25 percent of ultimate strength
GXSPORD1039	4.3.8.0-2	Any glass element subject to loads exceeding 10% of its ultimate tensile strength **shall** satisfy one of the following: "Safe-life" fracture analysis, "Fail-safe" analysis, or proof load testing at 1.0 times the load level.
GXSPORD1040	4.3.9	**4.3.9 Mechanisms**

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GXSPORD1041	4.3.9.0-1	Deployment, sensor, pointing, drive, separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.
GXSPORD1042	4.3.9.0-2	All GXS mechanisms **shall** have torque ratios greater than 1.2 while operating in an earth gravity environment with any orientation of the gravity vector.
GXSPORD1043	4.3.9.0-3	For the on orbit operational conditions, moving mechanical assemblies **shall** have torque and force ratios per section 2.4.5.3 of GSFC-STD-7000 using the Torque / Force Margin of Safety Table listed in GXSPORD1044.
GXSPORD1044	4.3.9.0-4	Torque/Force Margin of Safety Table

Program Phase	Known Torque Factor of Safety (FSk)	Variable Torque Factor of Safety (FSv)
Preliminary Design Review	2.00	4.0
Critical Design Review	1.50	3.0
Acceptance/Qualification Test	1.50	2.0

ID	Object Number	Text
GXSPORD1045	4.3.9.0-5	For all operating points of the actuators, all rotational actuators **shall** have available a continuous maximum torque output greater than 7.0 milli-Newton meters.
GXSPORD1046	4.3.9.0-6	For all operating points of the actuators, all linear actuators **shall** have available a continuous maximum force output greater than 0.28 N.
GXSPORD1047	4.3.9.0-7	For mechanisms using closed-loop control, gain and phase margins **shall** be greater than 12 dB, and greater than 40 degrees, respectively including the effects of the dynamic properties of any flexible structure.
GXSPORD1048	4.3.9.0-8	All mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.
GXSPORD1049	4.3.9.0-9	All mechanisms requiring restraint **shall** be released from a caged condition by command.
GXSPORD1050	4.3.9.0-10	All mechanisms requiring restraint **shall** be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.
GXSPORD1051	4.3.9.0-11	Mechanisms **shall** avoid brush-type motors for critical applications. Intentionally excluded from this rule are contacting sensory and signal power transfer devices (i.e., slip rings).
GXSPORD1052	4.3.9.0-12	When the instrument design includes micro-switches, the GXS **shall** use micro-switches for status conditions in telemetry only.
GXSPORD1053	4.3.9.0-13	The GXS **shall** not use micro-switches in logic or command circuits.
GXSPORD1054	4.3.10	**4.3.10 Pressurized Units**

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GXSPORD1055	4.3.10.0-1	The GXS pressurized systems **shall** follow the requirements in accordance with NASA-STD-8719.24 for the design of pressurized systems.
GXSPORD1056	4.3.10.0-2	The GXS **shall** have no open fluid reservoirs when delivered to the spacecraft contractor.
GXSPORD1057	4.3.11	**4.3.11 Alignment Reference**
GXSPORD1058	4.3.11.0-1	The GXS Sensor Unit **shall** have an optical alignment cube.
GXSPORD1059	4.3.11.0-2	The GXS Sensor Unit **shall** have a flight worthy cover for the optical alignment cube.
GXSPORD1060	4.3.11.0-3	The GXS Sensor Unit **shall** have fiduciary marks locating the X, Y, and Z axes of the unit.
GXSPORD1061	4.3.12	**4.3.12 Precision Component Assembly**
GXSPORD1062	4.3.12.0-1	When precise location of a component is required, the design **shall** use a stable, positive location system without relying on friction as the primary means of attachment.
GXSPORD1063	4.3.12.0-2	The GXS Sensor Unit spacecraft interface **shall** use a stable, positive location system without relying on friction as the primary means of attachment.
GXSPORD1064	4.4	**4.4 Thermal Requirements**
GXSPORD1065	4.4.1	**4.4.1 Mission Allowable Temperatures**
GXSPORD1066	4.4.1.0-1	The thermal design **shall** establish Mission Allowable Temperatures (MAT) for all mission phases including launch, orbit raising, ascent, and on-orbit operations.
GXSPORD1067	4.4.1.0-2	Worst-case thermal analyses **shall** include a minimum of 5° C of mandatory uncertainty to establish component MAT. Note: The uncertainty value during the design phase is expected to be larger, narrowing as the design matures, and at the conclusion of Instrument-level thermal testing the MAT still contains the 5° C of mandatory uncertainty.
GXSPORD1068	4.4.1.0-3	The GXS **shall** maintain all GXS subsystems within MAT limits during instrument operations.
GXSPORD1069	4.4.2	**4.4.2 Thermal Gradients**
GXSPORD1070	4.4.2.0-1	The GXS Contractor **shall** establish thermal gradient limits for all instrument subsystems operating on-orbit.
GXSPORD1071	4.4.2.0-2	The GXS **shall** maintain all instrument subsystems within thermal gradient limits during instrument operations.
GXSPORD1072	4.4.3	**4.4.3 Non-Operational Temperatures**
GXSPORD1073	4.4.3.0-1	The thermal design **shall** establish Non-Operational Temperatures (NOT) for all mission phases including launch, orbit raising, ascent, and on-orbit operations.

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GXSPORD1074	4.4.3.0-2	Worst-case thermal analyses **shall** include a minimum of 5º C of mandatory uncertainty to establish component NOT. Note: The uncertainty value during the design phase is expected to be larger, narrowing as the design matures, and at the conclusion of Instrument-level thermal testing the NOT still contain the 5º C of mandatory uncertainty.
GXSPORD1075	4.4.3.0-3	The GXS **shall** maintain all GXS subsystems within NOT limits when instrument is powered off.
GXSPORD1076	4.4.4	**4.4.4 Thermal Control Hardware**
GXSPORD1077	4.4.4.0-1	The GXS **shall** consist of two or more serial and independent controls for disabling any heater where any failed "ON" condition would cause over-temperature conditions or exceedance of the GXS power budget.
GXSPORD1078	4.4.4.0-2	All GXS heaters **shall** be sized to have maximum of 70% duty cycle for worst case conditions and minimum voltage.
GXSPORD1079	4.4.4.0-3	The GXS survival heaters **shall** be thermostatically controlled.
GXSPORD1080	4.4.5	**4.4.5 Detector Cooling Margin**
GXSPORD1081	4.4.5.0-1	The GXS detector cooling margin **shall** be greater than 30%.
GXSPORD1082	4.4.5.0-2	For new designs without heritage, the GXS detector cooling margin should be greater than: a) 45% up to and including Preliminary Design Review (PDR) b) 40% up to and including Critical Design Review (CDR)
GXSPORD1083	4.4.5.0-3	The GXS detector cooling margin is the excess system cooling capability divided by the heat load (including End of Life (EOL) dissipations, parasitics and external fluxes). For multistage cooling systems, the margin applies to the total system.
GXSPORD1084	4.4.6	**4.4.6 Radiator**
GXSPORD1085	4.4.6.0-1	The GXS radiator heat rejection margin **shall** be greater than or equal to 10% at the Pre-Environmental Review (PER) milestone.
GXSPORD1086	4.4.6.0-2	For new designs without heritage, the GXS radiator heat rejection margin should be greater than or equal to: (1) 20% leading up to and at PDR and (2) 15% leading up to and at CDR.
GXSPORD1087	4.4.7	**4.4.7 Heat Pipe (Two-phase Heat Transfer Device)**
GXSPORD1088	4.4.7.0-1	All GXS heat pipes and two-phase heat transfer devices **shall** have heat transport margin greater than or equal to 30%.

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GXSPORD1089	4.4.7.0-2	All GXS constant conductance and variable conductance heat pipes **shall** meet their performance requirements as verified by acceptance testing on each heat pipe at component-level in a gravity neutral orientation without relying on reflux. The GXS system-level heat pipe network may rely on reflux during Instrument and Satellite-level thermal testing. Note: Exceptions to this requirement will be considered for flight-qualified constant conductance heat pipes of identical design and similar use.
GXSPORD1090	4.4.7.0-3	All GXS heat pipes **shall** be functional during the Instrument-level and Observatory-level thermal-vacuum testing in either heat pipe mode or reflux mode.
GXSPORD1091	4.4.7.0-4	Any filter element in the GXS thermal system **shall** meet flow rate and pressure drop requirements when subjected to up to four times the expected contamination load.
GXSPORD1092	4.5	**4.5 Power Requirements**
GXSPORD1093	4.5.1	**4.5.1 Power Regulators and Supplies**
GXSPORD1094	4.5.1.0-1	The power regulators and power supplies **shall** operate with a phase margin of greater than 45 degrees over the on-orbit operational load, on-orbit operational temperature range, and on-orbit operational input voltage.
GXSPORD1095	4.5.1.0-2	The power regulators and power supplies **shall** operate with a gain margin of greater than 12dB over the on-orbit operational load, on-orbit operational temperature range, and on-orbit operational input voltage.
GXSPORD1096	4.5.2	**4.5.2 Fuses**
GXSPORD1097	4.5.2.0-1	The GXS **shall** not contain fuses.
GXSPORD1098	4.5.3	**4.5.3 Covers for test Connectors**
GXSPORD1099	4.5.3.0-1	The GXS **shall** have flight qualified covers for all test point connectors.
GXSPORD1100	4.5.4	**4.5.4 Keyed Connectors**
GXSPORD1101	4.5.4.0-1	The GXS **shall** employ uniquely labeled and keyed connectors in the instrument design.
GXSPORD1102	4.6	**4.6 Onboard Processors Requirements**
GXSPORD1103	4.6.1	**4.6.1 Flight Load Non-Volatile Memory**
GXSPORD1104	4.6.1.0-1	The entire GXS flight software image **shall** be contained in non-volatile memory at launch.
GXSPORD1105	4.6.2	**4.6.2 Commandable Reinitialization**
GXSPORD1106	4.6.2.0-1	The GXS On-board Processor **shall** provide for reset by command.
GXSPORD1107	4.6.2.0-2	The GXS On-board processor **shall** provide an unambiguous indication that a power on reset has occurred.

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GXSPORD1108	4.6.3	**4.6.3 Deterministic Power-on Configuration**
GXSPORD1109	4.6.3.0-1	The GXS On-board processor **shall** initialize upon power-up into a predetermined configuration.
GXSPORD1110	4.6.4	**4.6.4 Fail-safe Recovery Mode**
GXSPORD1111	4.6.4.0-1	The GXS **shall** provide a fail-safe recovery mode dependent on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.
GXSPORD1112	4.7	**4.7 Flight Software Requirements**
GXSPORD1113	4.7.1	**4.7.1 Language and Methodology**
GXSPORD1114	4.7.1.0-1	All GXS flight software **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. With NASA approval, minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers.
GXSPORD1115	4.7.2	**4.7.2 Flight Software Upload**
GXSPORD1116	4.7.2.0-1	The GXS flight software **shall** be reprogrammable on-orbit.
GXSPORD1117	4.7.2.0-2	The GXS flight software **shall** be uploaded without disturbing normal operations and data processing.
GXSPORD1118	4.7.2.0-3	The GXS modified flight software **shall** accept commands within 5 minutes of initiation of a computer restart.
GXSPORD1119	4.7.3	**4.7.3 Flexibility and Ease of Software Modification**
GXSPORD1120	4.7.3.0-1	The GXS flight software **shall** be deterministic in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.
GXSPORD1121	4.7.3.0-2	The Contractor **shall** organize all GXS software data that are modifiable and examinable by ground operators (e.g., tables or configuration parameters), so that they can be loaded and dumped by the ground system without reference to memory address.
GXSPORD1122	4.7.3.0-3	The definition of GXS commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.
GXSPORD1123	4.7.3.0-4	The GXS flight software, and associated on-board computer hardware, **shall** provide for loading any location and any size of on-board programmable memory upon command.
GXSPORD1124	4.7.4	**4.7.4 Version Identifiers**
GXSPORD1125	4.7.4.0-1	The Contractor **shall** implement all software and firmware versions with an internal identifier (embedded in the executive program) that can be included in the GXS engineering data.

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GXSPORD1126	4.7.4.0-2	The Contractor **shall** key the software identifier to the configuration management process.
GXSPORD1127	4.7.5	**4.7.5 Flight Processor Resource Sizing**
GXSPORD1128	4.7.5.0-1	During development, the GXS flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown in the Flight Software Resource Utilization Limits Table listed in GXSPORD1129 below (measured as a percentage of total available resource capacity):
GXSPORD1129	4.7.5.0-2	Flight Software Resource Utilization Limits Table

	Mission Phase (with Method)			
	FSW SRR	FSW PDR	FSW CDR	Ship/Flight
Resource	Estimate	Analysis	Analysis/ Measured	Measured
Average CPU Usage	50%	50%	60%	70%
Deadlines	50%	50%	60%	70%
PROM	50%	70%	80%	100%
EEPROM	50%	50%	60%	70%
RAM	50%	50%	60%	70%
PCI Bus	25%	30%	40%	50%
1553 Bus	70%	75%	80%	90%
Spacewire (1355)	70%	70%	70%	70%
UART/Serial I/F	50%	50%	60%	70%

GXSPORD1130	4.7.6	**4.7.6 Software Event Logging**
GXSPORD1131	4.7.6.0-1	The GXS flight software **shall** include time-tagged event logging in telemetry.
GXSPORD1132	4.7.6.0-2	The GXS event messages **shall** include all anomalous events, mode transitions, and system performance events.
GXSPORD1133	4.7.6.0-3	All GXS flight software components **shall** utilize a common format for event messages.
GXSPORD1134	4.7.6.0-4	The GXS flight software **shall** provide a means to enable and disable generation of individual event messages by command.
GXSPORD1135	4.7.6.0-5	The GXS flight software **shall** buffer a minimum of 1000 event messages.
GXSPORD1136	4.7.6.0-6	The GXS event message queue **shall** be configurable by command to either (a) discard the new events, or (b) overwrite oldest events when the queue is full.

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GXSPORD1137	4.7.6.0-7	The GXS flight software **shall** maintain counters for: a) The total number of event messages generated b) The number of event messages discarded because of queue overflow c) The number of event messages not queued due to being disabled
GXSPORD1138	4.7.7	**4.7.7 Warm Restart**
GXSPORD1139	4.7.7.1	**4.7.7.1 Processor Re-Start**
GXSPORD1140	4.7.7.1.0-1	The GXS flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.
GXSPORD1141	4.7.7.2	**4.7.7.2 Autonomous Re-Start**
GXSPORD1142	4.7.7.2.0-1	The GXS **shall** preserve information (i.e., flight software status, fault information, event message queue, parameter data tables, etc.) across autonomous flight computer resets for the purpose of diagnosing the cause of the reset.
GXSPORD1143	4.7.8	**4.7.8 Memory Integrity**
GXSPORD1144	4.7.8.1	**4.7.8.1 Memory Verification**
GXSPORD1145	4.7.8.1.0-1	The GXS flight software **shall** provide a mechanism to verify the contents of all memory areas.
GXSPORD1146	4.7.8.2	**4.7.8.2 Bit Error Detection and Correction**
GXSPORD1147	4.7.8.2.0-1	The GXS **shall** correct correctable errors and identify their location.
GXSPORD1148	4.7.8.2.0-2	The GXS **shall** identify the location of uncorrectable errors.
GXSPORD1149	4.7.9	**4.7.9 Memory Dump**
GXSPORD1150	4.7.9.0-1	The GXS flight software, and associated on-board computer hardware, **shall** provide the capability to dump any location and any size of on-board memory to the ground upon command.
GXSPORD1151	4.7.9.0-2	The GXS flight software memory dump capability **shall** not disturb normal operations and instrument data processing.
GXSPORD1152	4.7.10	**4.7.10 Telemetry Cadence and Dwell Control**
GXSPORD1153	4.7.10.0-1	The GXS flight software **shall** control the timing of each telemetry packet with an on-orbit modifiable table.
GXSPORD1154	4.7.11	**4.7.11 Long-Duration Test**
GXSPORD1155	4.7.11.0-1	The GXS flight software **shall** demonstrate 72 hours of error-free operations-like scenarios on the flight software development environment (FSDE).
GXSPORD1156	4.7.12	**4.7.12 Unnecessary and Unreachable Software**
GXSPORD1157	4.7.12.0-1	The GXS flight software **shall** not contain unused and unreachable code.

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GXSPORD1158	5	**5 Ground Support Equipment and Development**
GXSPORD1159	5.1	**5.1 Electrical System Test Equipment**
GXSPORD1160	5.1.0-1	The Electrical System Test Equipment (ESTE) **shall** operate the instrument and ground support equipment during performance verification and calibration testing.
GXSPORD1161	5.1.0-2	The ESTE **shall** simulate the spacecraft interface with power, clock pulses, command, and telemetry functions.
GXSPORD1162	5.1.0-3	The ESTE **shall** include all test equipment necessary to operate and control the GXS in all phases of operation and test modes.
GXSPORD1163	5.1.0-4	The ESTE **shall** generate and maintain command logs.
GXSPORD1164	5.1.0-5	The ESTE **shall** limit check all health and safety data.
GXSPORD1165	5.1.0-6	The ESTE **shall** capture and archive all raw data.
GXSPORD1166	5.1.0-7	The ESTE **shall** provide near-real time and off line data analysis of all data necessary to determine the performance characteristics of the GXS.
GXSPORD1167	5.1.0-8	The ESTE **shall** interface with the Spacecraft Ground Support Equipment at the Spacecraft Contractor's facility to extract science and engineering data.
GXSPORD1168	5.1.0-9	All ESTE units **shall** be interchangeable, without modification.
GXSPORD1169	5.1.0-10	The ESTE **shall** prohibit hazardous or critical commands being sent to the imager without operator verification.
GXSPORD1170	5.2	**5.2 Flight Software Development Environment**
GXSPORD1171	5.2.0-1	The Flight Software Development Environment (FSDE) **shall** consist of the hardware and software systems used for realtime, closed loop testing on flight like hardware to develop, test, validate, and demonstrate the flight software is ready for Government acceptance.
GXSPORD1172	5.2.0-2	The FSDE **shall** support all lifecycle activities (development, test, and validation) simultaneously.
GXSPORD1173	5.2.0-3	The FSDE **shall** contain all items (software, databases, compilers, debuggers, etc.) needed to prepare flight software for the target processor.
GXSPORD1174	5.2.0-4	The FSDE **shall** contain engineering (hardware) models of necessary flight hardware as well as dynamic software models comprising the remainder of the instrument and the necessary on-orbit environment.
GXSPORD1175	5.2.0-5	The FSDE **shall** have an all-software capability for simulating each interface to the Flight Software.
GXSPORD1176	5.2.0-6	The FSDE **shall** provide high-fidelity interface simulation for both nominal and anomalous data inputs, configurable in real-time, to the Flight Software.
GXSPORD1177	5.3	**5.3 Ground Processing Demonstration System**

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GXSPORD1178	5.3.0-1	The Ground Processing Demonstration System (GPDS) **shall** support playback of instrument data recorded during spacecraft I&T. This data will be ingested into the Ground Segment's (GS's) GPA for data operations exercises, and this capability will help troubleshooting of operational GS's implementation.
GXSPORD1179	5.4	**5.4 FM and GSE Shipping Containers**
GXSPORD1180	5.4.0-1	The GXS FM and GSE shipping containers **shall** be compatible with shipment by air or air-ride van.
GXSPORD1181	5.4.0-2	The GXS FM shipping container **shall** be climate controlled and purgeable.
GXSPORD1182	5.4.0-3	The GXS FM shipping container **shall** have internal temperature, humidity, and pressure monitors with external indicators.
GXSPORD1183	5.4.0-4	The GXS FM shipping container **shall** have shock recorders.
GXSPORD1184	5.4.0-5	The GXS FM shipping container **shall** meet all contamination control requirements imposed on the instrument units.
GXSPORD1185	5.4.0-6	The GXS FM and GSE shipping containers **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

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GXSPORD1186	6	# 6 GXS Simulators
GXSPORD1187	6.1	## 6.1 GXS Instrument Hardware Simulator (GXS-IHS)
GXSPORD1188	6.1.0-1	The GXS-IHS will be used to: a) Validate command procedures including: 1) Normal Operational Command Procedures 2) Contingency Operational Command Procedures 3) Memory uploads (Software Images, tables, etc.). b) Train operational personnel for normal and contingency operations c) Provide initial check out of the spacecraft command and telemetry interface
GXSPORD1189	6.1.0-2	The GXS-IHS **shall**: a) Model the capabilities of the memory, cards, and motor drivers so that GXS-IHS will accurately simulate all instrument modes and mode transitions. b) Execute GXS flight code. c) Generate housekeeping, engineering, and diagnostic telemetry data reflective of commanded mode and imaging pattern. d) Accept simulation control commands from a standalone console. e) Maintain a log of all simulation directives received. f) Accept real-time inputs to change simulated telemetry or modeling parameters. g) Generate predefined science data streams that reflect the size and rate of the actual science data. h) Simulate predefined, scripted anomalies. i) Simulate failures that are detected by the instrument controller software. j) Override any telemetry point that is not generated by the Flight Software, to either a static value or to ramp the value over time. k) Implement a scheme to allow the user to update the default configuration information nominally stored in EEPROM. l) Communicate with a Spacecraft Hardware Simulator (SHS) for instrument command, telemetry, and science packets using SpaceWire. m) Accept simulation control commands from the Spacecraft Hardware Simulator (SHS). n) Run in real-time or faster. o) Use commercial power.
GXSPORD1190	6.2	## 6.2 GXS Instrument Software Simulator (GXS-ISS)
GXSPORD1191	6.2.0-1	The GXS-ISS **shall**: a) Process all commands from the Instrument Telemetry and Command Handbook and generate housekeeping, engineering, and diagnostic telemetry responses that are representative of instrument operation.

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GXSPORD1191	6.2.0-1	b) Provide telemetry in the same format as the instrument (GRDDP). c) Provide software emulation of onboard instrument processor code execution to reproduce instrument flight software processing. d) Provide software emulation of onboard memory functions. e) Include representative modeling of the thermal response to commanded state changes and operational, diagnostic, and contingency modes of the instrument. f) Include representative modeling of voltages and currents in response to commanded state changes and operational, diagnostic, and contingency modes of the instrument. g) Generate output data produced by the instrument that is used by the spacecraft bus for attitude control (e.g. predicted interface forces and torques generated during operations). h) Provide correctly formatted instrument high-rate science data streams and timed fill packets for data flow purposes (note: reading from internally stored data suffices). i) Enable execution of operational instrument test scripts to provide representative instrument responses. j) Enable simulation of contingencies over all operational modes of the instrument, including automated fault management response and redundant component response. k) Provide a capability to inject an abrupt failure, a degraded performance or erratic behavior, and the ability to override model-produced instrument telemetry and insert chosen values. l) Be compatible with the Satellite Software Simulator's (SSS) execution time. When SSS is operating in accelerated time (up to 4x) the GXS Software Simulator (GXS-ISS) only provides housekeeping and engineering telemetry (no science data). As described in item (h) , when the GXS-ISS is invoked to operate in a real-time mode, it provides instrument's housekeeping, engineering, and science data with fill blocks.

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GXSPORD1192	7	# 7 FM Design Verification Requirements
GXSPORD1193	7.0-1	The following requirements represents only a portion of the overall GXS system verification (i.e., Contractor-derived requirements are not described) that must be integrated into the total system program which verifies that the FM will meet the mission requirements. A system performance verification program documenting the overall verification plan, implementation, and results is required which will provide traceability from mission specification requirements to launch and initial on-orbit capability. This will also provide the baseline for tracking on-orbit performance versus pre-launch capability.
GXSPORD1194	7.1	**7.1 Powered-on Operating Time and Trouble-Free Performance Testing**
GXSPORD1195	7.1.0-1	The GXS FM **shall** accumulate a minimum of one-thousand (1000) hours of operating/powered-on time on each of the primary and redundant sides, prior to shipment.
GXSPORD1196	7.1.0-2	The GXS FM instrument-level testing **shall** demonstrate trouble-free operation for at least the last 350 hours of powered operation on each of the primary and redundant sides prior to shipment.
GXSPORD1197	7.1.0-3	The GXS FM **shall** demonstrate trouble-free operation for at least the last 350 hours of powered operation on each of the primary and redundant sides prior to launch.
GXSPORD1198	7.1.0-4	The GXS FM instrument-level thermal-vacuum hours **shall** include 100 trouble-free hours collected at the hot operational plateau on each of the primary and redundant sides.
GXSPORD1199	7.1.0-5	The GXS FM instrument-level thermal-vacuum hours **shall** include 100 trouble-free hours collected at the cold operational plateau on each of the primary and redundant sides.
GXSPORD1200	7.1.0-6	The last 350 hours of operating/power-on time of GXS FM **shall** include at least 200 hours collected in thermal-vacuum on each electronics side prior to launch.
GXSPORD1201	7.2	**7.2 Structural and Mechanical Verification Requirements**
GXSPORD1202	7.2.1	**7.2.1 Mechanical Test Factors and Duration**
GXSPORD1203	7.2.1.0-1	The GXS instrument units **shall** survive testing while employing the mechanical test factors and durations shown in the GXS Test Factors and Durations Table listed in GXSPORD1208. The random and sinusoidal levels may be notched to prevent the interface forces from exceeding the forces derived from the limit static acceleration loads.
GXSPORD1204	7.2.1.0-2	The GXS Instrument units **shall** undergo and survive random vibration testing with the loads at the interface of the instrument units corresponding to the limit levels defined in GIRD392 multiplied by the test factors in the GXS Test Factors and Durations Table referenced in GXSPORD1208. The levels may be notched to prevent the interface forces from exceeding the forces derived from the limit static acceleration loads.

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GXSPORD1205	7.2.1.0-3	The GXS Instrument units **shall** undergo and survive sinusoidal vibration testing with the loads at the interface of the instrument units corresponding to the limit levels defined in GIRD395 multiplied by the test factors in the GXS Test Factors and Durations Table referenced in GXSPORD1208. The levels may be notched to prevent the interface forces from exceeding the forces derived from the limit static acceleration loads.
GXSPORD1206	7.2.1.0-4	The GXS Instrument qualification unit **shall** undergo and survive acoustics testing to the acoustic levels defined in GIRD404 multiplied by the test factors in the GXS Test Factors and Durations Table referenced in GXSPORD1208.
GXSPORD1207	7.2.1.0-5	The GXS Instrument units **shall** undergo and survive shock testing with the loads at the interface of the instrument units corresponding to the limit levels defined in GIRD399 multiplied by the test factors in the GXS Test Factors and Durations Table referenced in GXSPORD1208.
GXSPORD1208	7.2.1.0-6	**GXS Test Factors and Durations Table**

Test	Prototype Qualification	Protoflight Qualification	Acceptance
Structural Loads[1]			
Level	1.25 x Limit Load	1.25 x Limit Load	1.0 x Limit Load
Duration			
Centrifuge/Static Load	1 minute	30 seconds	30 seconds
Sine Burst	5 cycles @ full level per axis	5 cycles @ full level per axis	5 cycles @ full level per axis
Acoustics[2]			
Level[3]	Limit Level + 3dB	Limit Level + 3dB	Limit Level
Duration	2 minutes	1 minute	1 minute
Test	Prototype Qualification	Protoflight Qualification	Acceptance
Random Vibration			
Level[3]	Limit Level + 3dB	Limit Level + 3dB	Limit Level
Duration	2 minutes/axis	1 minute/axis	1 minute/axis
Sine Vibration[4]			
Level	1.25 x Limit Level	1.25 x Limit Level	Limit Level
Sweep Rate	2 oct/min	4 oct/min	4 oct/min
Mechanical Shock[5]			
Actual Device	2 actuations	2 actuations	1 actuation
Simulated	1.4 x Limit Level 2 x each axis	1.4 x Limit Level 1 x each axis	Limit Level 1 x each axis

1 - Test levels for weldments, beryllium, bonded and composite structure including metal matrix are 1.25 x Limit Level for both Qualification and Acceptance testing. Not required for electronics boxes.

2 - Required for qualification unit only.

3 - At a minimum, the test level should be equal to or greater than the workmanship

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GXSPORD1208	7.2.1.0-6	level. 4 - Waived for electronics boxes with fundamental modes over 100 Hz. 5 - May be deferred to spacecraft level testing for shock insensitive components with project approval.
GXSPORD1340	7.2.1.0-7	At a minimum, the Random and Acoustics test levels defined in the GXS Test Factors and Durations Table (GXSPORD1208) **shall** be equal to or greater than the respective workmanship levels.
GXSPORD1209	7.2.2	**7.2.2 Minimum Workmanship**
GXSPORD1210	7.2.2.0-1	All electrical, electronic, and electro-mechanical components **shall** be subjected to minimum workmanship test levels as specified in the Minimum Workmanship Test Levels Table listed in GXSPORD1211.

GXSPORD1211 7.2.2.0-2 **Minimum Workmanship Test Levels Table**

Frequency (Hz)	ASD Level (g^2/Hz)
20	0.01
20-80	+3 dB/oct
80-500	0.04
500-2000	-3 dB/oct
2000	0.01
Overall	6.8 g_{rms}

The plateau acceleration spectral density level (ASD) may be reduced for components weighing between 45.4 and 182 kg, or 100 and 400 pounds according to the component weight (W) up to a maximum of 6dB as follows;

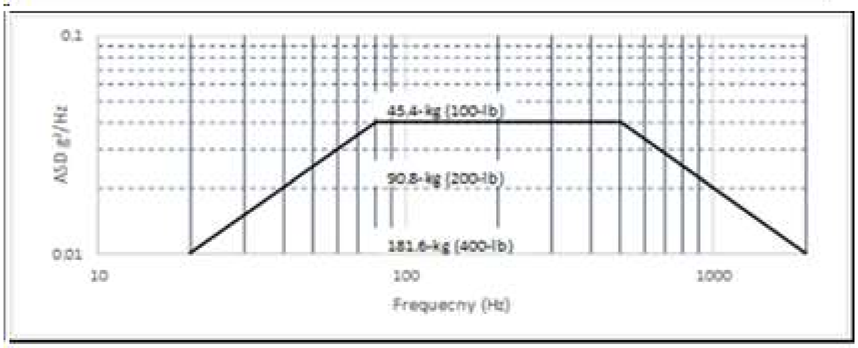
	Weight in kg	Weight in lb
dB reduction	= 10 log(W/45.4)	10 log(W/100)
$ASD_{Plateau}$ level	= 0.04*(45.4/W)	0.04*(100/W)

The sloped portions of the spectrum shall be maintained at plus and minus 3 dB/oct. Therefore, the lower and upper break points, or frequencies at the ends of the plateau become:

F_L = 80 (45.4/W) [kg] F_L = frequency break point low end of plateau
= 80 (100/W) [lb]

F_H = 500 (W/45.4) [kg] F_H = frequency break point high end of plateau
= 500 (W/100) [lb]

The test spectrum shall not go below 0.01 g2/Hz. For components whose weight is greater than 182-kg or 400 lbs, the workmanship test spectrum is 0.01 g2/Hz from 20 to 2000 Hz with an overall level of 4.4 g_{rms}.



GXSPORD1212 7.2.3

7.2.3 Testing in Flight Configuration

GXSPORD1213 7.2.3.0-1 Mechanical environmental testing of flight hardware **shall** be performed with the test article in its flight configuration.

GXSPORD1214 7.2.4

7.2.4 Structural Proof Testing

GXSPORD1215 7.2.4.0-1 The GXS structures containing critical welds, bonded joints, beryllium, and nonmetallic composites (including metal matrix), on each FM build, **shall** survive proof testing to 1.25 times limit load.

GXSPORD1216 7.2.4.0-2 Prior to proof testing, bonded hardware **shall** be thermally cycled to the protoflight temperature extremes.

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GXSPORD1217	7.2.5	**7.2.5 Modal Survey Characterization**
GXSPORD1218	7.2.5.0-1	GXS Instrument Unit modal frequencies up to 75 Hz and with more than 5% predicted modal mass participation **shall** correlate to modeled frequencies with accuracy of 5% as verified by test.
GXSPORD1219	7.2.5.0-2	GXS Instrument Unit mode shapes with frequencies up to 75 Hz and with more than 5% predicted modal mass participation **shall** correlate to modeled mode shapes with respect to the modeled modal mass matrix with greater than 90% on the diagonal and less than 10% off of the diagonal as verified by test.
GXSPORD1220	7.2.6	**7.2.6 Structural Qualification**
GXSPORD1221	7.2.6.0-1	The FM flight hardware **shall** be mechanically tested to the values found in GXS Test Factors and Durations Table listed in GXSPORD1208.
GXSPORD1222	7.2.6.0-2	Any glass elements with bonds **shall** be qualified with a non-flight prototype.
GXSPORD1223	7.2.6.0-3	The number of qualification tests on a non-flight prototype **shall** be greater than or equal to the planned number of acceptance tests performed on any flight unit.
GXSPORD1224	7.2.6.0-4	The qualification tests **shall** reduce the input levels as necessary to prevent the unit interface forces from exceeding the yield limits defined in the GIRD.
GXSPORD1225	7.2.6.0-5	The acceptance tests **shall** reduce the input levels as necessary to prevent the interface forces from exceeding the flight limits defined in the GIRD.
GXSPORD1226	7.2.6.0-6	Vibration tests **shall** be performed to provide test data sufficient to update structural models, to compute responses to launch loads using updated models, and to verify margins against yield and ultimate strength requirements in the 50.1 to 100 Hz frequency range.
GXSPORD1227	7.2.6.0-7	For shock isolated units, the lower frequency limit of the input shock spectrum **shall** be less than 0.7 times the frequency of the first natural mode of the isolated unit.
GXSPORD1228	7.2.7	**7.2.7 Deployment and Articulation Verification**
GXSPORD1229	7.2.7.0-1	All flight deployables, movable appendages, and mechanisms **shall** demonstrate full range of motion and articulation under worst-case and flight-like conditions (including blankets) while driven by flight electronics prior to flight.
GXSPORD1230	7.2.8	**7.2.8 Life Test**
GXSPORD1231	7.2.8.0-1	Except for active cryogenic cooling systems, a life test **shall** be conducted, within representative operational environments, to at least 2x expected life for all repetitive motion devices with a goal of completing 1x expected life by CDR.
GXSPORD1232	7.2.8.0-2	For active cryogenic cooling systems, the total operating time or number of operational cycles without failure **shall** be at least 1.0 times mission life with 0.5 times mission life completed prior to the scheduled launch date of the first flight model.
GXSPORD1233	7.2.9	**7.2.9 Mechanical Clearance Verification**

ID	Object Number	418-XO-GXSPORD-0118, RM Version, GeoXO Sounder (GXS) Performance and Operational Requirements Document (PORD) Phase B
GXSPORD1234	7.2.9.0-1	Verification of mechanical clearances and margins including potential reduced clearances after blanket expansion **shall** be performed on the final as-built hardware.
GXSPORD1235	7.3	**7.3 Electromagnetic Compatibility Verification**
GXSPORD1236	7.3.1	**7.3.1 General**
GXSPORD1237	7.3.1.0-1	The design requirements for Electromagnetic Compatibility (EMC) / Electromagnetic Interference (EMI) design are listed in the GIRD and the GXS UIID. They also comprise test requirements and they are not repeated here. The qualification and flight acceptance tests for the EMC program are the same. The EMC test program is intended to ensure compatibility of the GXS units with the GeoXO spacecraft, uncover workmanship defects, and identify unit-to-unit variation in electromagnetic characteristics as well as design flaws. The EMC/EMI requirements described below also apply to all spare and previously qualified hardware.
GXSPORD1238	7.3.2	**7.3.2 Electrostatic Arc-Discharge Susceptibility**
GXSPORD1239	7.3.2.0-1	The GXS **shall** be designed to preclude or minimize the impact of ESD events.
GXSPORD1240	7.3.2.0-2	The GXS **shall** be designed to withstand both a radiated and direct arc as shown in the ESD Characteristics Table listed in GXSPORD1247 without sustaining permanent damage.
GXSPORD1241	7.3.2.1	**7.3.2.1 External Surface-to-Surface direct discharge**
GXSPORD1242	7.3.2.1.0-1	The direct arc-discharge can occur on any of the exposed surfaces of the instrument. The GXS **shall** not be impaired by differential charging between its external surfaces.
GXSPORD1243	7.3.2.2	**7.3.2.2 Deep Dielectric Charging**
GXSPORD1244	7.3.2.2.0-1	The GXS **shall** withstand all direct discharges caused by deep dielectric charging (Internal Electrostatic Discharge, IESD). Terminating all unused wires within a harness and terminating all unused pins within connectors will minimize the magnitude of charge build up.
GXSPORD1245	7.3.2.3	**7.3.2.3 ESD Characteristics**
GXSPORD1246	7.3.2.3.0-1	Test or analysis **shall** be used to show that the instrument operation will not be impaired after an arc discharge with the characteristics listed in the ESD Characteristics Table listed in GXSPORD1247.
GXSPORD1247	7.3.2.3.0-2	**ESD Characteristics Table**

Item	Description	Characteristics
1	Discharge Voltage	10 kV
2	Discharge Energy	3 millijoules, maximum
3	Peak Current	1 Amp

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GXSPORD1247 7.3.2.3.0-2

4	Time Constant	600 nsec
5	Repetition Rate	1 sec
6	Quantity of Discharges per Surface	≥ 30
7	Distance of Radiated Discharge from Instrument Surface	30 cm

GXSPORD1248 7.4

7.4 Thermal Test Requirements

GXSPORD1249 7.4.1

7.4.1 General

GXSPORD1250 7.4.1.0-1 All GXS flight hardware **shall** be subjected to thermal-vacuum testing.

GXSPORD1251 7.4.1.0-2 The thermal-vacuum tests **shall** exercise flight hardware to produce the maximum and minimum dissipation in components including operation over the range of possible applied voltages.

GXSPORD1252 7.4.1.0-3 The thermal-vacuum tests **shall** demonstrate survival mode and survival heater margin, as well as operational heaters and their margin.

GXSPORD1253 7.4.1.1

7.4.1.1 Thermal Test Chronology

GXSPORD1254 7.4.1.1.0-1 Thermal Balance (TB) and Thermal Vacuum (TV) testing may occur as individual or combined tests. If combined, the test **shall** satisfy the requirements of both the TB and the TV tests.

GXSPORD1255 7.4.1.1.0-2 Regardless of whether Thermal Balance (TB) is a combined or separate test, TB **shall** precede TV, thereby allowing the TB results to refine the TV plateau temperatures if appropriate. The permissible exception to this is that the first hot plateau may be combined with bake-out prior to TB.

GXSPORD1256 7.4.1.2

7.4.1.2 Pressure

GXSPORD1257 7.4.1.2.0-1 The chamber pressure during TB and TV **shall** be maintained at less than 1.33 X 10^{-3} Pa. (1 X 10^{-5} Torr).

GXSPORD1258 7.4.1.2.0-2 The chamber pressure **shall** be monitored during TB and TV testing.

GXSPORD1259 7.4.1.2.0-3 The chamber GSE **shall** provide a "pressure alarm" for loss of vacuum.

GXSPORD1260 7.4.1.2.0-4 In the event of a pressure alarm, the test system **shall** take autonomous action to safe the flight hardware.

GXSPORD1261 7.4.2

7.4.2 Thermal Vacuum

GXSPORD1262 7.4.2.1

7.4.2.1 Transition Rates

GXSPORD1263 7.4.2.1.0-1 The temperature rates of change **shall** be at least the expected orbital temperature transition rate.

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GXSPORD1264	7.4.2.1.0-2	The temperature rates of change **shall** be less than 1.25 times the maximum predicted orbital temperature transition rate.
GXSPORD1265	7.4.2.2	**7.4.2.2 Corona Operation**
GXSPORD1266	7.4.2.2.0-1	Hardware that is electrically powered during launch **shall** be operated through chamber pump down to demonstrate that it will not sustain damage though the corona voltage breakdown regime.
GXSPORD1267	7.4.2.3	**7.4.2.3 Hot and Cold Start Demonstrations**
GXSPORD1268	7.4.2.3.0-1	The flight hardware **shall** demonstrate cold starts under vacuum from minimum NOT, with the added test margins appropriately applied, at least once per each side (primary/redundant).
GXSPORD1269	7.4.2.3.0-2	The flight hardware **shall** demonstrate cold starts at minimum input voltage.
GXSPORD1270	7.4.2.3.0-3	The flight hardware **shall** demonstrate hot starts under vacuum from maximum NOT, with the added test margin appropriately applied, at least once per each side (primary/redundant).
GXSPORD1271	7.4.2.3.0-4	The flight hardware **shall** demonstrate hot starts at maximum input voltage.
GXSPORD1272	7.4.2.4	**7.4.2.4 Heater Verification**
GXSPORD1273	7.4.2.4.0-1	GXS FM TV testing **shall** demonstrate the ability of survival heaters to maintain the GXS flight hardware within NOT limits during worst cold environments with margin, at minimum voltage and while the GXS is powered off.
GXSPORD1274	7.4.2.4.0-2	Cold plateau testing **shall** demonstrate that operational heaters maintain the GXS components within their Protoflight and Acceptance temperature ranges, for PFM and FM, respectively, based on predictions from thermal analyses.
GXSPORD1275	7.4.2.4.0-3	The plateau dwell duration **shall** be sufficient for achieving temperature stability for Thermal Balance.
GXSPORD1276	7.4.2.4.0-4	Operational heater set points, survival heater set points, and heater control **shall** be independently verified.
GXSPORD1277	7.4.2.4.0-5	Heater duty cycle less than 70% at the worst cold case and at minimum voltage **shall** be demonstrated.
GXSPORD1278	7.4.2.5	**7.4.2.5 Flight Temperature Sensor Verification**
GXSPORD1279	7.4.2.5.0-1	Instrument-level TV testing **shall** corroborate flight temperature sensors against test temperature sensors in at least the bounding hot and cold temperature conditions.
GXSPORD1280	7.4.3	**7.4.3 TV Thermal Cycling**
GXSPORD1281	7.4.3.0-1	TV Cycling consists of cycling between temperature extremes for the purpose of checking operability over broad temperature ranges while inducing stress to uncover workmanship defects and other flaws.
GXSPORD1282	7.4.3.1	**7.4.3.1 Cumulative Cycles**

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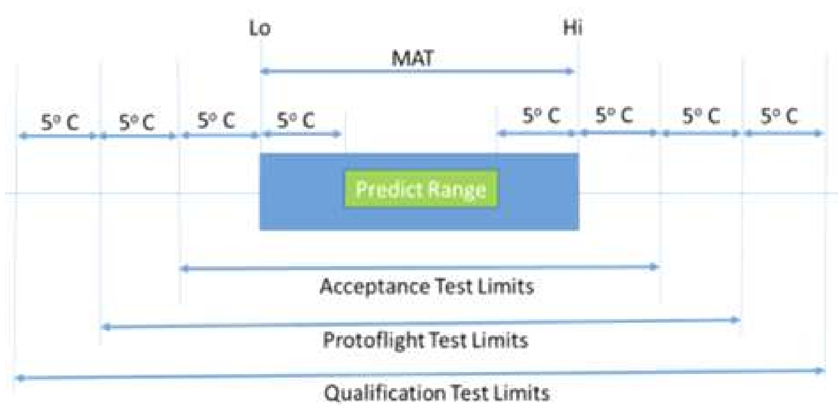
GXSPORD1283	7.4.3.1.0-1	Every GXS Instrument Unit **shall** undergo 12 TV cycles prior to launch; this applies to flight spares as well as to repaired units.
GXSPORD1284	7.4.3.1.0-2	There **shall** be a minimum of eight (8) thermal-vacuum cycles at the instrument level of TV testing prior to shipment.
GXSPORD1285	7.4.3.1.0-3	Four TV cycles are planned during spacecraft thermal testing. The GXS **shall** be operating during spacecraft-level thermal vacuum testing.
GXSPORD1286	7.4.3.1.0-4	The thermal plateaus **shall** be of minimum of 12 hrs or sufficient duration to conduct functional testing whichever is greater.
GXSPORD1287	7.4.3.1.0-5	The GXS **shall** be tested to the Protoflight or Acceptance limits shown in Test Temperature Description Figure listed in GXSPORD1293.
GXSPORD1288	7.4.3.1.0-6	The GXS **shall** be operated, and its performance monitored, during hot and cold plateaus as well as during hot and cold transitions.
GXSPORD1289	7.4.3.2	**7.4.3.2 Ambient Pressure Thermal Cycling Substitution**
GXSPORD1290	7.4.3.2.0-1	GXS **shall** not substitute ambient pressure testing in lieu of thermal vacuum testing.
GXSPORD1291	7.4.3.3	**7.4.3.3 Qualification, Protoflight and Acceptance Temperatures**
GXSPORD1292	7.4.3.3.0-1	The test temperature description is provided below in the Test Temperature Description Figure shown in GXSPORD1293.
GXSPORD1293	7.4.3.3.0-2	**Test Temperature Description Figure** 
GXSPORD1294	7.4.3.3.0-3	Qualification, proto-flight and acceptance verification test procedures **shall** be the same except for adjustments in test temperature differentials.
GXSPORD1295	7.4.3.3.0-4	The Qualification test temperature **shall** be 15°C warmer than the maximum MAT and 15°C colder than the minimum MAT as shown in Test Temperature Description Figure shown in GXSPORD1293.
GXSPORD1296	7.4.3.3.0-5	Protoflight test temperature **shall** be 10°C warmer than the maximum MAT and 10° C colder than the minimum MAT as shown in Test Temperature Description Figure shown in GXSPORD1293.

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GXSPORD1297	7.4.3.3.0-6	Acceptance test temperature **shall** be 5°C warmer than the maximum MAT and 5°C colder than the minimum MAT as shown in Test Temperature Description Figure shown in GXSPORD1293.
GXSPORD1298	7.4.3.3.0-7	For components with operational heater circuits, the Protoflight and Acceptance test temperature **shall** be 5°C colder than the minimum MAT.
GXSPORD1299	7.4.3.3.0-8	The survival heater temperature set point **shall** be used as the cold NOT, if mechanical thermostats are employed.
GXSPORD1300	7.4.3.4	**7.4.3.4 Survival Heater Verification**
GXSPORD1301	7.4.3.4.0-1	Thermal testing **shall** verify that the GXS thermal design and thermal control system maintain hardware between the upper and lower NOT limits.
GXSPORD1302	7.4.3.5	**7.4.3.5 Temperature test tolerances**
GXSPORD1303	7.4.3.5.0-1	In lieu of more specific instructions or requirements, TV test temperature tolerances **shall** be ±2° C.
GXSPORD1304	7.4.3.6	**7.4.3.6 Plateau Criteria**
GXSPORD1305	7.4.3.6.0-1	Thermal vacuum soak **shall** be based upon measurements from representative temperature sensor(s) or an average of measurements from such sensors.
GXSPORD1306	7.4.3.6.0-2	The sensor measurements **shall** be representative of the temperatures of units or critical parts of the payload.
GXSPORD1307	7.4.3.6.0-3	Temperature soaks **shall** begin when the "control" temperature is: within ±2° C of the proposed test temperature and the temperature rate of change is less than 1° C/hour.
GXSPORD1308	7.4.4	**7.4.4 Thermal Balance (TB)**
GXSPORD1309	7.4.4.0-1	The TB tests **shall** validate the adequacy of the thermal design by operating the hardware in the worst hot and worst cold case thermal environments.
GXSPORD1310	7.4.4.1	**7.4.4.1 Balance Points**
GXSPORD1311	7.4.4.1.0-1	Two compulsory TB points **shall** simulate the worst hot operating environment and the worst cold operating environment.
GXSPORD1312	7.4.4.1.0-2	A third compulsory thermal balance test point **shall** verify survival heater margins at the worst cold case environment.
GXSPORD1313	7.4.4.1.0-3	Additional balance point(s) **shall** be required for case(s) that challenge the thermal control system in ways not demonstrated during the compulsory balance points.
GXSPORD1314	7.4.4.2	**7.4.4.2 Instrument Configuration**
GXSPORD1315	7.4.4.2.0-1	For TB, the test units **shall** be in flight-like configuration including: a) Coatings and finishes b) MLI

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GXSPORD1315	7.4.4.2.0-1	c) Mounting hardware and isolators d) Flight heaters and thermostats e) Heat pipes preferably horizontal or alternatively in reflux mode
GXSPORD1316	7.4.4.3	**7.4.4.3 Accuracy and Knowledge**
GXSPORD1317	7.4.4.3.0-1	For the Thermal Balance test cases, the simulated environments **shall** replicate at least 95% of the expected orbital energy values.
GXSPORD1318	7.4.4.3.0-2	The hot and cold simulated environment **shall** be measured, characterized and understood to ±2% of the instrument thermal model values.
GXSPORD1319	7.4.4.3.0-3	During or prior to TB testing, unit power dissipation (in all relevant modes) **shall** be measured and characterized to at least a 2% accuracy.
GXSPORD1320	7.4.4.3.0-4	Prior to TB testing, the test harness losses (voltage drops) **shall** be measured and characterized.
GXSPORD1321	7.4.4.3.0-5	Conductive heat losses due to test harnesses **shall** be less than 3% of the GXS heat balance.
GXSPORD1322	7.4.4.3.0-6	Guard heater (Zero-Q) **shall** be used to minimize uncontrolled heat leaks through test harnesses and any other non-flight component that could affect the thermal-balance results.
GXSPORD1323	7.4.4.3.0-7	In addition to the flight sensors, additional test sensors **shall** be located throughout the Instrument to assist thermal model validation/correlation.
GXSPORD1324	7.4.4.3.0-8	Thermal targets (adiabatic coupons) **shall** be used to correctly produce simulated environments around the test article.
GXSPORD1325	7.4.4.4	**7.4.4.4 Steady State Criteria**
GXSPORD1326	7.4.4.4.0-1	The TB conditions **shall** be considered stable (at equilibrium) when for the final 3 hours: 1) Each control temperature sensor's variation is less than 0.20° C/hour, 2) Temperature/Time plots exhibit slopes with a magnitude that is decreasing over the 3 hour period, 3) Temperatures are within 2°C of the extrapolated equilibrium temperature.
GXSPORD1327	7.5	**7.5 Test Condition Tolerances**
GXSPORD1328	7.5.0-1	In the absence of a rationale for other test condition tolerances, the values listed in the Test Condition Tolerances Table listed in GXSPORD1329 **shall** be used; the values include measurement uncertainties.
GXSPORD1329	7.5.0-2	

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GXSPORD1329	7.5.0-2	Test Condition Tolerances Table

Test Condition Tolerances Table

Acoustics	Overall Level:	≤ 1 dB	
	I/3 Octave Band Tolerance:	Frequency (Hz)	Tolerance (dB)
		f ≤ 40	+3, -6
		40 < F < 3150	±3
		f ≥ 3150	+3, -6
	Duration	+10%, -0%	
Antenna Pattern Determination		± 2 dB	
Electromagnetic Compatibility	Voltage Magnitude:	± 5% of the peak value	
	Current Magnitude:	± 5% of the peak value	
	RF Amplitudes:	± 2 dB	
	Frequency:	± 2 %	
	Distance:	± 5% of specified distance or ± 5 cm, whichever is greater	
Humidity		± 5% RH	
Loads	Steady-State (Acceleration):	± 5%	
	Sine Burst Amplitude:	± 5%	
	Static:	± 5%	

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GXSPORD383	8	**8 Acronyms**

GXSPORD384 8.0-1

CDR	Critical Design Review
EOL	End of Life
ESD	Electro-Static Discharge
ESTE	Electrical System Test Equipment
FM	Flight Model
FOR	Field of Regard
FSDE	Flight Software Development Environment
FTS	Fourier Transform Spectrometer
FWHM	Full-Width-Half-Maximum
GeoXO	Geostationary-eXtended Observations
GIRD	General Interface Requirements Document
GPA	Ground Processing Algorithm
GSA	Ground Sample Angle
GSD	Ground Sample Distance
GSE	Ground Support Equipment
GXS	GeoXO Sounder
ILS	Instrument Line-shape Function
INR	Image Navigation and Registration
IR	Infrared
K	Kelvin
kHz	Kilohertz
km	Kilometers
L1b	Level 1b
m	meters
MAT	Mission Allowable Temperature
Mbps	Mega-bits-per-second
MLI	Multi-Layer Insulation
MMD	Mean Mission Duration
mW	Milliwatt
NASA	National Aeronautics and Space Administration
NEDN	Noise Equivalent Delta Radiance
NEDT	Noise Equivalent Delta Temperature
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOT	Non-Operating Temperature
PDR	Preliminary Design Review
PORD	Performance Operational Requirements Document
rad	Radian
RMS	Root Mean Square
SD	Sounding Disk
SNR	Signal-to-Noise Ratio
sr	Steradian
TB	Thermal Balance
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TDI	Time Delay and Integration
TM	Thermal Margin
TV	Thermal Vacuum

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GXSPORD385	8.0-2	UIID	Unique Instrument Interface Document
		µm	Micrometers (Microns)
		µrad	Microradian

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