Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Solar Imaging Suite (SIS)

Performance and Operational Requirements Document (PORD)

Baseline Version

May 3, 2004

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

To verify the correct version of this document, please contact the GOES R Series Requirements Management Office on 301-286-7898

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1 Scope

1.1 Identification

This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Solar Imaging Suite (SIS).

1.2 Mission Review

The SIS objectives are as follows:

-Measure the magnitude of solar X-ray flux.

-Determine the solar EUV flux from 5 to 127 nm.

- Locate coronal holes for forecasts of recurring geomagnetic activity.

- Locate flares for forecasts of solar energetic particle events.

- Assess active region complexity for flare forecasts.

- Determine occurrence of coronal mass ejections (CME’s) and CME width, extent, velocity, and mass (or relative brightness).

The SIS instruments provide data to the Ground System, designated as SIS-GS in this document, via the spacecraft communication system. The SIS-GS takes the SIS data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates products for the NOAA users. This requirements document only applies to the SIS instruments, but the SIS contractor must have an understanding of the total system to assure that the SIS-GS will be able to provide the required data.

1.3 Document Overview

This document contains all performance requirements for the SIS suite of instruments and the Ground Support Equipment (GSE). This document, the General Interface Requirements Document (GIRD), and the SIS Unique Instrument Interface Document (UIID) define all instrument to spacecraft interfaces for the SIS.

1.4 Terminology

The term "(TBD)" which means "to be determined", applied to a missing requirement means that the instrument contractor determines the missing requirement.

The term "(TBR)", which means "to be refined/reviewed", means that the requirement is subject to review for appropriateness and subject to revision. The contractor is liable for compliance with the requirement as if the "TBR" notation did not exist. The "TBR" merely provides an indication that the value is more likely to change in a future modification than requirements not accompanied by a "TBR".

1.5 Definitions

Throughout this document, the following definitions apply:

Accuracy: Refers to the error in a measurement, that is the difference between the measured and 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 and a Standard Deviation calculated. The magnitude of a random error **shall** be taken as three standard deviations (3σ).

All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the GIRD, SIS PORD or the SIS Unique Instrument Interface Requirements Document (SIS UIID).

Cadence: The time interval between the start of successive data collection sequences.

Data Latency: The time interval between the end of a data collection sequence and the time that the data is available at the spacecraft interface.

Detector sample or element: Refers to the output of a physical detector after the Analog-to-Digital (A/D) converter and Time Delay and Integration (TDI) processing, if applicable.

Eclipse: Defined as when the solar disk is completely or partially occulted by the Earth or Moon as viewed from the spacecraft.

Flux Resolution: Minimum difference in flux which can be measured; usually determined by the Analog-to-Digital Converter.

Full Disk: Defined as 42 arc-min diameter - 1.3 times the visible solar diameter.

Fully Functional Configuration: Being able to collect the full complement of science data; determine instrument response changes; acquisition of sensor health and status data; generation of sensor, calibration, monitoring, health and status data streams; and reception and execution of command and control data.

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle.

Measurement Resolution: Resolution of the A/D converter.

Pixel: Applies to calibrated and navigated data samples (after resampling during the ground processing if required).

Goal**:** A requirement that is desirable to achieve as closely as possible.

Precision: Refers to the standard deviation (1σ) of a statistically meaningful number of samples of a measurement.

Resolution: Ability to distinguish two adjacent features in the spectral, spatial or temporal domain.

Scanline: Refers to any line of pixels that extends in an East-West direction across the Sun or space in the format of GOES SIS data.

Station Keeping: On-orbit spacecraft maneuver that corrects for orbital drifts.

Threshold: A requirement which must be met.

Transfer Orbit: The sequence of events that transpires to establish the GOES-R series satellite on-station after the GOES-R series satellite has separated from the launch vehicle.

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.

Yaw Flip: An on-orbit maneuver that rotates the spacecraft 180º about the spacecraft z axis (yaw). The net effect reverses the signs of the roll and pitch axes while maintaining yaw pointing at nadir.

1.6 Requirement Applicability

All requirements apply over the entire life of the SIS. All requirements in this SIS PORD apply to data after all ground processing except as indicated.

1.7 Requirement Weighting Factors

The requirements stated in this SIS PORD are not of equal importance or weight. The following paragraphs define the weighting factors incorporated in this document.

- **Shall** designates the most important weighting level; that is, mandatory. Any deviations from these contractually imposed mandatory requirements require the approval of the NASA contracting officer.

- Will designates a lower weighting level. These will requirements designate the intent of the Government and are often stated as examples of acceptable designs, items, and practices. Unless required by other contract provisions, noncompliance with the will requirements does not require approval of the NASA contracting officer and does not require documented technical substantiation.

- May designates the lowest weighting level, possibility, or discretion of the Government or contractor.

2 Applicable Documents

Various parts of this requirements document refer to some of these documents.

CCSDS Recommendation for Space Data System Standard, Lossless Data Compression, CCSDS 121.0-B-1, May 1997.

Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001, June 21, 1996.

General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document

Number MIL-A-83577B, February 1, 1988.

Space Mechanisms Handbook, Document Number NASA-TP-1999-206988.

General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components, Document Number GSFC GEVS-SE, June 1, 1996.

Eastern and Western Range Policies and Procedures, Document Number EWR-127-1, October 23, 2000.

Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522, September 4, 1992.

Collisional Plasma Models with APEC/APED: Emission-Line Diagnostics of Hydrogen-like and Helium-like Ions, Smith et. al., *Astrophysical Journal*, 556, L91-L95, 2001

3 SIS Sensor Requirements

The following requirements apply to all instruments of the SIS.

Each instrument **shall** be able to operate independently.

3.1 Sensor Definition

3.1.1 SIS Modes

The SIS Instruments **shall** execute commands to individually enable and disable each autonomous function.

All SIS Instrument Modes and their function **shall** be documented in the Interface Control Document (ICD).

Each SIS Instruments **shall** initiate all commanded mode transitions within10 seconds after receipt of command.

The SIS instruments **shall** make limits and triggers of autonomous functions changeable by command.

The SIS instruments **shall** transition from their current mode to any other mode without causing permanent damage to themselves.

The SIS instruments **shall** indicate the mode of the instrument in housekeeping telemetry.

The SIS instruments **shall** provide command and housekeeping telemetry functions in all powered modes.

3.1.1.1 Safe Mode

Each instrument of the SIS **shall** implement a Safe Mode.

The SIS instruments **shall** be in a thermally and optically safe configuration for an indefinite period of time while in Safe Mode.

The SIS instruments **shall** enter Safe Mode upon detection of internal faults that are capable of causing permanent damage to the instrument.

Transitions to Safe Mode, whether commanded or autonomous, **shall** require no more than 1 second to initiate.

Transition from Safe Mode to Normal Operational Mode **shall** not exceed 10 minutes.

3.1.1.2 Normal Operational Mode

The SIS instruments **shall** implement a Normal Operational Mode. In Normal Operational Mode, the SIS instruments **shall** be in a fully functional configuration.

3.1.1.3 Instrument Diagnostic Mode

Each SIS Instrument **shall** implement an Instrument Diagnostic Mode.

In Instrument Diagnostic Mode the instrument **shall** be in a fully functional configuration.

In Instrument Diagnostic Mode, the instrument **shall,** as a minimum have the following capabilities:

- Send data from all detectors.

- Send the same data both compressed and uncompressed to allow ground evaluation of the impact of compression on the data.

- Send all bits from the A/D converter.

- Perform electronic in-flight calibration.

In all of the above requirements, the data channels to be sent to the spacecraft will be selected to stay within the allocated data rate.

The SIS **shall** by command send dwell data (increased samples per second of a particular telemetry measurand) while in Diagnostic Mode.

3.1.1.4 On-Orbit Storage Mode

The SIS instruments **shall** be in a configuration during on-orbit storage mode that provides protection to the entrance apertures from contamination and micrometeorites.

3.1.2 On-Orbit Operations

The SIS **shall** be able to conduct regular operations, i.e., Normal Operational Mode, while flying aboard a 3-axis stabilized, geostationary spacecraft with orbital limit constraints as stated in the General Interface Requirements Document (GIRD) and/or the SIS Unique Interface Document (UIID).

The SXI **shall** be capable of interrupting Normal Operations and Instrument Diagnostics by command and starting the acquisition of a new image observation sequence after a new image sequence upload, within 30 seconds. If it is powered down to conserve spacecraft power it **shall** be capable of returning to full operations within 10 minutes after power is applied.

3.1.2.1 Reserved

3.1.2.2 Reserved

3.1.2.3 Eclipse

The SIS instruments **shall** be capable of continuous operation through eclipse periods.

From the time immediately following eclipse until four hours (TBR) after eclipse, the SXI line of sight **shall** be pointed to within ±6 arcminutes, 3σ, of the sun center

From the time immediately following eclipse until four hours (TBR) after eclipse, the SXI line of sight pointing **shall** not drift during an exposure more than ±4 arcseconds, 3σ.

From the time immediately following eclipse until four hours (TBR) after eclipse, the line of sight pointing knowledge **shall** be ±5 arcseconds, 3σ.

All pointing requirements of section 3.1.1 of this PORD **shall** be met within four hours (TBR) after eclipse.

3.1.2.4 Operations After Maneuvers

3.1.2.4.1 Yaw Flip

The SIS instruments **shall** be able to operate in a spacecraft yaw flip mode. The spacecraft contractor is required to provide the capability to perform a biannual flip about the yaw axis, where the yaw axis is defined as the nadir-pointing axis, such that the nominal north face of the spacecraft points south.

The SIS instruments **shall** meet all requirements within 10 minutes (TBR) after the spacecraft interface has returned to being within specification following a yaw flip.

3.1.2.4.2 Station Keeping

The SIS instruments **shall** meet all requirements within 10 minutes (TBR) after the spacecraft interface has returned to being within specification following spacecraft station keeping maneuvers.

3.1.2.4.3 Post Storage Activation

The SIS instruments **shall** meet all requirements within 1 day of instrument turn-on after on-orbit storage activation.

3.2 Sensor Requirements

3.2.1 SIS Pointing Requirements

The following sections define the pointing requirements for the individual instruments in the SIS. The SIS instruments **shall** be coaligned on a common platform.

The SIS **shall** meet the requirements stated in the subsections below when subjected to the interfaces stated in the GIRD.

3.2.1.1 SXI Pointing Requirements

3.2.1.1.1 Pointing Accuracy

The SIS **shall** maintain the SXI line of light to within +/- 2.4 arc-min, 3 -sigma, of the Sun center, during normal operations.

3.2.1.1.2 Pointing Stability

The line of sight pointing **shall** not drift during an exposure (~20 seconds) more than ±2 arc-sec, 3σ, (Goal: ±1 arc-sec) and not more than ±1 arc-min over a 24-hour period.

3.2.1.1.3 Pointing Knowledge

The line of sight pointing knowledge of the SXI **shall** be ± 2.5 arcseconds, 3 sigma.

3.2.1.2 Extreme Ultraviolet Sensor (EUVS) and X-Ray Sensor (XRS) Pointing Requirements

3.2.1.2.1 Pointing Knowledge

During normal operation, the knowledge of the XRS and EUVS boresight pointing with respect to the sun center **shall** be ±2 arcminutes, 3σ, with a measurement precision of ±1 arcminute when the sun center is within ±2º of the lines of sight of the instruments.

3.2.1.3 Pointing Data Telemetry

The SIS instruments **shall** provide SIS pointing data for each fo the transmitted images, with the same latency as the image data.

3.2.2 SXI Sensor Requirements

3.2.2.1 Sensor Definition

3.2.2.1.1 SXI Overview and Description

The SXI is a coronal imager capable of operating in the soft X-ray to EUV wavelength range (henceforth referred to as the XUV range). It provides full-disk solar images at high cadence around the clock except for brief periods during an eclipse. Available combinations of exposures and filters allows the coverage of the entire dynamic range of solar X-ray features, from coronal holes to X-class flares, as well as the estimate of temperature and emission measure. The operational goals are to: locate coronal holes for geomagnetic storm forecasts, detect and locate flares for forecasts of solar energetic particle events related to flares, monitor changes in the corona that indicate coronal mass ejections (CMEs) detect active regions beyond east limb for F10.7 forecasts, and analyze active region complexity for flare forecasts.

3.2.2.2 Field of View

The SXI **shall** acquire full spatial resolution data from all spectral channels.

The field of view (FOV) **shall** be 42.0 arc-min by 42.0-arc-min minimum.

The SXI **shall** have square picture elements (pixels) with a maximum size of 5 arc-sec by 5 arc-sec.

3.2.2.3 Point Response

The sampled data output from the image when illuminated by a point source **shall** meet the requirements stated in the following table over the instrument's measurement range and spectral range. The table below describes the percentage of the total energy from the X-ray source that falls within a square area of a given diameter for those pixels which are in their linear response range. Demonstration of this requirement can be accomplished by use of multiple exposures if necessary to accommodate signal-to-noise and dynamic range. The specification is at the system level and therefore includes all optical and detection components.

Point Response Requirement in Terms of Ensquared Energy

Encircled Energy	Threshold Side (arc sec)	Goal Side (arc sec)
48%	7	5
87%	14	10
91%	21	15
96%	35	25
99%	56	40

Point response **shall** be uniform to ±30% (Goal ±10%) across the entire field of view.

3.2.2.4 System Spectral Response

The physical coronal parameters to be remotely sensed by SXI are representations of the plasma temperature and emission measure. Specifically, the objective is to provide intensity measurements in a set of wavelength ranges that most effectively allow retrieval of the Differential Emission Measure (DEM) defined below.

Model Differential Emission Measures for Solar Features (See Note)

		Coronal Hole		Quiet Corona		Active Region		Flare	
	T	**DEM**	**Error**	**DEM**	**Error**	**DEM**	**Error**	**DEM**	**Error**
	5.5	20.29	±0.342	20.30	±0.342	20.50	±0.342	21.70	±0.342
	5.6	20.33	±0.301	20.20	±0.301	20.40	±0.301	21.70	±0.301
	5.7	20.36	±0.255	20.20	±0.255	20.40	±0.255	21.70	±0.255
	5.8	20.36	±0.204	20.30	±0.204	20.50	±0.204	21.70	±0.204
	5.9	20.32	±0.146	20.40	±0.146	20.60	±0.146	21.75	±0.146
	6.0	20.28	±0.146	20.70	±0.079	20.80	±0.079	21.80	±0.079
	6.1	20.20	±0.146	20.90	±0.079	21.00	±0.079	21.90	±0.079
	6.2	20.00	±0.146	20.80	±0.079	21.20	±0.079	22.00	±0.079
	6.3	19.70	±0.204	20.50	±0.079	21.30	±0.079	22.10	±0.079
	6.4	19.20	±0.255	20.10	±0.079	21.30	±0.079	22.25	±0.079
Threshold	6.5	18.50	±0.301	19.70	±0.146	21.10	±0.079	22.40	±0.079
	6.6	N/A	N/A	19.20	±0.204	20.80	±0.079	22.55	±0.079
	6.7	N/A	N/A	18.60	±0.255	20.30	±01.46	22.70	±0.079
	6.8	N/A	N/A	N/A	N/A	19.50	±0.204	22.95	±0.079
	6.9	N/A	N/A	N/A	N/A	18.50	±0.255	23.15	±0.079
	7.0	N/A	N/A	N/A	N/A	N/A	N/A	23.20	±0.079
	7.1	N/A	N/A	N/A	N/A	N/A	N/A	23.15	±0.146
	7.2	N/A	N/A	N/A	N/A	N/A	N/A	22.95	±0.204
	7.3	N/A	N/A	N/A	N/A	N/A	N/A	22.65	±0.255
	7.4	N/A	N/A	N/A	N/A	N/A	N/A	22.10	±0.301
	7.5	N/A	N/A	N/A	N/A	N/A	N/A	21.50	±0.342

Note: Base 10 logarithmic values of parameters are given.

The DEM reconstruction **shall** be performed as defined below to the uncertainties specified in the following table.

DEFINITIONS:

Temperature:

Temperature is defined in units of Kelvins. The Table gives the base 10 logarithmic value of the temperature grid for DEM evaluation. The grid is evenly spaced in the logarithmic domain. The threshold range covers $T = 1$ to 10 MK ($\mathrm{Log}_{10}(T)$=6.0 to 7.0). The goal range covers from $T = 0.5$ to 20 MK ($\mathrm{Log}_{10}(T)$=5.7 to 7.3). Grid bins may be considered to be evenly spaced in the logarithmic domain, e.g., the bin centered on $\mathrm{Log}_{10}(T)$=6.5 would begin at $\mathrm{Log}_{10}(T)$=6.45 and end at $\mathrm{Log}_{10}(T)$=6.55.

Differential Emission Measure:

The differential emission measure used in this SISPORD is the column emission measure per unit temperature as defined by:

$$DEM_C = \int \frac{n_e^2}{dT} dx$$

where n_e^2 is the electron number density in units of cm^{-3}, dT is the temperature differential in units of Kelvins (K), x is the line of sight integration path in units of cm. Thus, DEM_C has units of cm^{-5}-K^{-1}. Integration of DEM_C over temperature yields the column emission measure. The Table gives the base 10 logarithmic value of the DEM_C to be evaluated on the temperature grid given.

Error:

The error allowable in the final retrieval of DEM information is per pixel and is defined in terms of a multiplicative error factor, e.g., a 20% error represents an error factor of 1.2. The base 10 logarithm of this error factor is given in the Table. For an error factor of 1.2, we have Log_{10}(Error)=0.079, which is *additive* in the logarithmic domain. For example, if $\text{Log}_{10}(DEM_C)=21.5 \pm 0.146$, then the uncertainty of the final DEM determination is allowed to range from $\text{Log}_{10}(DEM_C)=21.354$ to 21.646.

Radiance:

The plasma DEM and temperature are related to the radiance, R, as follows:

$$R = \frac{1}{4\pi} \int_T \int_\lambda DEM_C(T) F(\lambda, T) dT d\lambda$$

where F is the (photon) spectral emissivity per electron (cm^3 $Å^{-1}$ s^{-1}). Thus, radiance is in units of ph cm^{-2} sr^{-1} s^{-1}. This can also be expressed as cm^{-2} $arcsec^{-2}$ s^{-1}, in which case the incident photon rate on an SXI detector pixel, I_{pix}, would be computed as:

$$I_{pix} = \frac{\Omega}{4\pi} \int_T \int_\lambda DEM_C(T) F(\lambda, T) A_{eff}(\lambda) dT d\lambda$$

where Ω is the solid angle subtended by a detector pixel and A_{eff} is the instrument effective area as a function of wavelength. The units of the incident photons are counts per second. With the APEC/APED spectral model of Smith et al. (Collisional Plasma Models with APEC/APED: Emission-Line Diagnostics of Hydrogen-like and Helium-like Ions, *Astrophysical Journal*, 556, L91-L95, 2001.), the above equations can be represented in terms of energy (ergs) rather than photons (counts).

3.2.2.4.1 Out-of-Band Response

Out-of-band response from IR, visible, UV, EUV and/or X-ray radiation and in-band stray radiation **shall** be minimized as needed to meet DEM reconstruction (spectral response) requirements.

In addition a means of tracking unplanned out-of-band signal, e.g., that due to a filter failure, **shall** be provided.

3.2.2.4.2 Spatial Response Uniformity

The image **shall** be correctable so that when illuminated by a uniform source from a single exposure the calibrated telemetered image **shall** not vary by more than 5% across the field of view.

3.2.2.4.3 Photometric Resolution

The SXI **shall** be capable of providing a photometric resolution of at least 0.1% of the instrument's single exposure full-scale data output for radiances greater than 20 times the instrument's minimum detectable radiance.

The transfer function between the X-ray photon flux entering the instrument and the data output for each image pixel **shall** be a monotonic function of intensity from a monochromatic X-ray source.

3.2.2.4.4 Scattered Light and/or Blooming

Over exposure of the detector during a single raw data image integration by a point source with an incident flux exceeding the instrument full-scale response by a factor of 10^4 at the exposure used **shall** not cause the reported flux of any pixel 1 arc-min away from the point source image to increase by more than 20%, with a goal of 2%, of the maximum monotonic-response flux in any pixel more than 1 arc-min from the overexposed pixel(s).

3.2.2.5 Photometric Accuracy and Precision

3.2.2.5.1 Accuracy and Precision

The SXI **shall** measure radiance to an accuracy of ±20% (Goal: ±10%).

3.2.2.5.2 Short Term Stability

The accuracy of photometric products (calibrated pixel fluxes) **shall** not vary by more than +/-5% over a 24-hour period.

3.2.2.5.3 Long Term Stability

The photometric gain of the SXI **shall** not change by more than 20% over the operational lifetime of the instrument within normal operating environmental conditions.

3.2.2.5.4 Defective Pixels

The SXI processed data **shall** have less than 0.1% defective pixels.

No more than one tenth of the defective pixels **shall** be adjacent. A defective pixel is one that is not compliant with any single requirement listed in this PORD.

3.2.2.5.5 In-Flight Calibration

The SXI **shall** include a ground-commandable internal illumination source that can be used on-orbit, during pre-launch testing, and during spacecraft integration and test, as well as in flight, to verify the integrity of the detector and associated electronics and to provide a constant relative photometric standard throughout the instrument lifetime. As a goal, it should provide information to normalize the gain of the system (flat fielding).

The SXI system **shall** be able to insert a calibration signal upon command.

Means for close coordination between spacecraft and instrument operations **shall** be provided in order to support cooperative calibration procedures, e.g., a 'fast' slew of the instrument by the spacecraft or platform to provide flat-field response information.

3.2.2.6 Temporal Resolution

3.2.2.6.1 Single Spectral Passband

Full field-of-view, full spatial resolution images of the Sun, in a given spectral passband, **shall** be obtained and telemetered with a frequency such that an image covering the entire photometric measurement range can be constructed on the ground every two minutes (goal: every minute) under normal operations.

3.2.2.6.2 Multiple Spectral Passbands

Emission measure distribution as a function of temperature requires measurements in a minimum of three spectral passbands. Full field-of-view, full spatial resolution images of the Sun, in a minimum of three spectral passbands, **shall** be obtained and telemetered with a frequency such that a derived emission measure distribution image product covering the entire photometric measurement range can be constructed every six minutes (goal: every three minutes) under normal operations.

3.2.2.6.3 Data Latency

Data latency, from the completion of image integration to the transmission of the last image bit to the spacecraft data bus, **shall** be no more than 10 seconds.

3.2.2.7 Data and Control Capability

3.2.2.7.1 Partial Image Readout

The SXI **shall** be capable of providing partial images of the FOV via reading a limited area of the detector array.

The center and size of this partial readout area **shall** be configurable.

An on-board memory table **shall** be provided such that the location and size of the partial readout can be loaded as a function of time to account for feature motion with solar rotation. The intent is to enable a mode of operation analogous to Imager and Sounder 'mesoscale rapid scan' operations whereby a small region is imaged at a higher cadence than normal full disk cadence.

3.2.2.7.2 Data Compression

The SXI **shall** be able to provide pixel data in at least one lossless and at least one 'lossy' compression mode in addition to being able to provide the full, uncompressed data values.

3.2.2.7.3 Binning and Summing of Pixels

The SXI **shall** be capable of post-readout summing of pixels.

3.2.2.7.4 Automatic Bright Region Location and Tracking

The SXI **shall** implement an algorithm to determine the pixel centroid locations of up to the five brightest region locations for each exposure taken, depending on ground commanded intensity and minimum-number-of-pixels thresholds for bright region identification.

The SXI **shall** be configurable by ground command to take partial images centered on any or all of the five bright regions automatically identified.

3.2.2.7.5 Automatic Flare Location and Tracking

The SXI **shall** implement an algorithm to determine the pixel centroid location of a single flaring region for each exposure taken, depending on ground commanded intensity and minimum-number-of-pixels thresholds for bright region identification.

The thresholds for flare location **shall** be independent of those for bright region location.

The SXI **shall** be configurable by ground command to automatically transition to a different flare-imaging sequence that may take different whole disk images or may take partial images centered on the flare region automatically identified.

3.2.2.7.6 Image Summary Metadata

The SXI **shall** provide image metadata, defined as summary information about each exposure, prior to the completion of image telemetry. The information **shall** include, but not be limited to: flare location and summary information, bright region location and summary information, and image histogram information.

3.2.3 XRS Requirements

3.2.3.1 XRS Overview and Description

The GOES X-ray Sensor (XRS) is the primary measure of and standard for solar flare magnitude. Its primary function is to provide a means of detecting the beginning, duration, and magnitude of solar X-ray flares. Many space weather phenomena are preceded by a solar event such as a solar flare. In addition, the XRS is used as an input for the empirical model of Solar Energetic Proton events that can have severe impacts on satellites and astronauts. Two X-ray channels are required to monitor the disk-integrated solar fluxes in the 0.05 to 0.8 nm wavelength range at 3-second intervals. assumed.

The sensor **shall** be sensitive enough to permit quiet sun background measurements at low levels of solar activity as well as very large solar flares.

For calculations of threshold sensitivity, a $2x10^6$K solar spectrum such as the one presented by "Mewe and Groenshild, 1981, Astron. Astrophys. Suppl, Ser., vol 45, pp11-52" **shall** be assumed.

3.2.3.2 Spectral Bands

The XRS **shall** have two bands covering the spectral range of 0.05 to 0.8 nm.

The two bands **shall** be XRS-A: 0.05 - 0.4 nm and XRS-B: 0.1-0.8 nm, where band edges represent wavelengths where the instrument sensitivity drops below about 20% of the peak sensitivity.

3.2.3.3 Minimum and Maximum Flux

The minimum flux measurable by the XRS-A channel **shall** be less than 5 x 10^{-9} W m^{-2} (Goal: 1 x 10^{-9} Wm^{-2}) and the maximum flux **shall** be greater than 5 x 10^{-4} Wm^{-2} (Goal: 1 x 10^{-3} Wm^{-2}).

The minimum flux measurable by the XRS-B **shall** be less than 2 x 10^{-8} W m^{-2} (Goal: 1 x 10^{-8} Wm^{-2}) and the maximum flux **shall** be greater than 2 x 10^{-3} Wm^{-2} (Goal: 4 x 10^{-3} Wm^{-2}).

3.2.3.3.1 Out of Band Rejection

The out-of-band rejection **shall** be such that < 10% of the observed signal comes from out-of-band for a typical solar spectrum or some method of monitoring the out-of-band single **shall** be provided.

3.2.3.3.2 Long-term Stability

Over the duration of the mission, the XRS instrument response **shall** change by less than 5% or a method of tracking changes **shall** be provided.

3.2.3.3.3 Flux Resolution and Response

For the two X-ray channels, the resolution of the energy flux measurements **shall** be < 2% (Goal: ±1%) of the detected flux for fluxes > 20 times the minimum measurable fluxes specified in paragraph 3.2.3.3.

The telemetered data **shall** be a monotonic function of the input fluxes with deviations from a monotonic response function being less than ±2%.

3.2.3.3.4 Wavelength Response

The wavelength response for each of the two XRS channels **shall** be within ±25% of the previous GOES XRS instruments between the defined wavelengths (see tables).

XRS Wavelength Response Table

Relative wavelength response of the two XRS channels as a function of wavelength. The upper and lower limits are acceptable ranges of relative sensitivity while the preferred is similar to existing XRS instruments normalized to a peak sensitivity of one.

	XRS Short Channel			XRS Long Channel		
Wavelength (nm)	Preferred	Upper Limit	Lower Limit	Preferred	Upper Limit	Lower Limit
0.04	0.05	.016	0.02			
0.08	0.32	0.44	0.23	0.14	0.28	0.07
0.12	0.71	0.88	0.56	0.37	0.53	0.26
0.16	0.96	1.17	0.78	0.65	0.83	0.48
0.20	1.00	1.21	0.81	0.87	1.08	0.67
0.24	0.87	1.04	0.68	0.98	1.21	0.77
0.28	0.57	0.72	0.44	1.00	1.24	0.79
0.32	0.48	0.62	0.36	0.97	1.21	0.77
0.36	0.34	0.45	0.24	0.92	1.13	0.70
0.40	0.22	0.32	0.14	0.62	0.93	0.56
0.44	0.12	0.20	0.05	0.65	0.84	0.49
0.48	0.05	0.15	0.01	0.65	0.84	0.49
0.52	0.03	0.11	0.00	0.62	0.81	0.47
0.56				0.58	0.76	0.42
0.60				0.51	0.69	0.37
0.64				0.44	0.59	0.30
0.68				0.37	0.52	0.25
0.72				0.30	0.45	0.19
0.76				0.24	0.38	0.14
0.80				0.18	0.31	0.09
0.84				0.13	0.26	0.05
0.88				0.10	0.21	0.03
0.92				0.07	0.18	0.01
0.96				0.05	0.15	0.01

The wavelength response of each channel **shall** be measured to an accuracy of ±5%.

The instrument **shall** be calibrated at sufficient wavelengths to adequately characterize the wavelength response from each detector component with a wavelength-dependent response.

An analysis of the uncertainties and errors of each component **shall** be provided to verify that the number of calibration wavelengths is sufficient to adequately characterize the relative wavelength response to an accuracy of ±5%.

3.2.3.3.5 Measurement Accuracy

The accuracy of the X-ray flux product **shall** be ±10% with a goal of ±5% of the actual flux for flux values greater than 20 times the minimum measurable flux.

3.2.3.3.6 Signal to Noise

The signal level **shall** be such that at minimum (threshold) flux levels, the mean signal **shall** be greater than the standard deviation of the data (instrumental noise) over a 10 minute interval.

3.2.3.4 Electron Environment

The minimum performance of the XRS sensor **shall** not be compromised by the presence of the anticipated worst-case natural electron environment.

To allow for the fact that the trapped particle population is not isotropically distributed, a 2% peak-to-peak sinusoidal variation with angle **shall** be assumed superimposed on the average electron environment. The representation for the worst-case natural environment assumes isotropic flux with the spectral distribution shown in Table 6.9.

Assumed Worst-Case Electron Environment

E (MeV)	0.3	0.45	1.05	1.9
J(>E) (p cm^{-2} sec^{-1})	2×10^7	7×10^6	7×10^5	1.5×10^5

3.2.3.5 Temporal Resolution

A measurement **shall** be obtained every 3 sec with a goal of 0.5 seconds.

The data latency **shall** be no more than 1 second. (TBD).

The time delay between the XRS-A and XRS-B exposures **shall** be less than 0.1 seconds.

3.2.3.6 Spatial Coverage

The instrument **shall** provide a measurement of the full solar disk and the lower solar atmosphere (Diameter of 40 arc-min centered at sun-center).

3.2.3.7 In-flight Calibration

A calibration mode **shall** be provided by ground command for determining electronic processing gain to an accuracy of 2% for all channels and for verifying basic instrument functionality.

This calibration **shall** be traceable to incident flux through detector preflight calibration.

The in-flight calibration **shall** be both self-terminating and able to be terminated by ground command.

3.2.3.8 Pre-Flight Calibration

The complete XRS **shall** be calibrated for sensitivity to X-ray flux at a facility with an X-ray source traceable to the NIST Standard for X-ray calibration.

The accuracy of the calibration **shall** be such as to demonstrate that the X-ray calibrated product **shall** be within +/-10% (goal 5%) of the actual flux for flux values greater than 20 times the minimum measurable flux.

3.2.3.9 Pointing Accuracy and Angular Response

The instrument response, including the combined effect of spacecraft pointing and sensitivity variations across the sensor field-of-view, **shall** not deviate by more than 5% (goal 2%) for point sources of constant flux within 20 arc-min of the solar disk center.

3.2.4 EUVS Requirements

3.2.4.1 EUVS Overview and Description

Solar EUV radiation is a dominant energy source for the upper atmosphere and the ionizing radiation produces the ionosphere. Solar variability at these wavelengths is one of the primary drivers of thermospheric/ionospheric variability. Uncertainties in the solar EUV flux are a major source of errors in specification and modeling of the thermosphere and ionosphere. To provide adequate knowledge of this ionizing radiation, knowledge of the full EUV spectrum from 5 to 127 nm is required.

3.2.4.2 Wavelength Range

Measurements **shall** be made between 5 and 127 nm that would allow the reconstruction of the complete EUV spectrum with at least the resolutions defined below.

From 5 to 35 nm:	10 nm resolution
From 35 to 115 mn:	40 nm resolution
From 118 to 127 nm:	10 nm resolution

The instrument **shall** either measure more than 85% of the spectral range or provide a means of estimating the spectral region that is not measured from 5 to 127 nm.

3.2.4.3 Minimum Sensitivity and Dynamic Range

For each band or spectral element, the minimum observable flux **shall** be approximately 0.1 times the expected flux under solar minimum (1996) conditions.

The maximum observable flux **shall** be approximately 10 times the expected solar flux under solar maximum (2001) conditions.

These values can be found in Minimum and Maximum Flux Values table s**hall** be used to determine the

EUVS minimum sensitivity and dynamic range.

Minimum and maximum flux values that **shall** be used to determine the EUVS minimum sensitivity and dynamic range

MinFlux $W/m^2/nm$)	Max Flux ($W/m^2/nm$)	Wvlnth (nm)	MinFlux ($W/m^2/nm$)	Max Flux ($W/m^2/nm$)	Wvlnth (nm)	Min Flux ($W/m^2/nm$)	Max Flux ($W/m^2/nm$)
1.5E-6	2.8E-3	44.5	8.4E-7	7.6E-5	88.5	6.8E-6	4.0E-4
6.4E-6	3.3E-2	45.5	3.7E-7	6.1E-5	89.5	8.0E-6	7.7E-4
1.7E-6	3.5E-3	46.5	3.6E-6	2.9E-4	90.5	1.1E-5	7.1E-4
5.3E-6	8.4E-3	47.5	8.3E-7	7.4E-5	91.5	8.7E-6	5.4E-4
8.6E-6	3.1E-3	48.5	1.7E-6	1.1E-4	92.5	2.0E-6	1.7E-4
6.9E-6	2.0E-3	49.5	3.8E-6	2.3E-4	93.5	2.7E-6	1.5E-4
8.6E-6	2.3E-3	50.5	1.6E-6	1.9E-4	94.5	2.9E-6	1.9E-4
5.9E-6	2.6E-3	51.5	5.4E-7	8.8E-5	95.5	4.9E-7	9.6E-5
4.7E-6	2.4E-3	52.5	1.7E-6	1.9E-4	96.5	5.0E-7	9.1E-5
1.4E-6	2.7E-3	53.5	1.6E-6	6.3E-5	97.5	2.4E-5	2.0E-3
1.1E-6	2.3E-3	54.5	3.6E-7	5.8E-5	98.5	1.0E-6	2.2E-4
2.7E-7	3.0E-3	55.5	5.7E-6	1.8E-4	99.5	1.7E-6	2.0E-4
2.1E-7	2.8E-3	56.5	1.2E-6	5.1E-5	100.5	9.4E-7	9.6E-5
2.7E-7	2.1E-3	57.5	4.4E-7	6.4E-5	101.5	1.2E-6	6.9E-4
2.6E-6	9.5E-4	58.5	8.4E-6	4.6E-4	102.5	1.9E-5	1.0E-3
2.3E-6	7.5E-4	59.5	9.9E-7	7.5E-5	103.5	2.1E-5	1.0E-3
6.4E-7	1.9E-3	60.5	5.2E-6	2.1E-4	104.5	1.5E-6	1.8E-4
5.3E-6	7.7E-3	61.5	8.7E-8	1.4E-4	105.5	1.6E-6	1.3E-4
2.0E-5	3.7E-3	62.5	9.0E-6	3.1E-4	106.5	1.9E-6	1.5E-4
1.0E-5	5.0E-3	63.5	1.5E-7	2.5E-4	107.5	2.2E-6	1.7E-4
9.5E-6	5.2E-3	64.5	2.3E-7	3.6E-5	108.5	4.3E-6	3.2E-4
6.8E-6	1.2E-3	65.5	2.4E-7	3.2E-5	109.5	2.8E-6	1.9E-4
3.5E-6	3.9E-3	66.5	4.0E-7	5.0E-5	110.5	1.4E-6	2.3E-4
2.0E-6	3.4E-4	67.5	2.9E-7	3.2E-5	111.5	1.7E-6	1.9E-4
3.7E-6	5.6E-4	68.5	1.0E-6	4.8E-5	112.5	9.8E-7	2.3E-4
4.4E-6	1.8E-3	69.5	4.4E-7	4.1E-5	113.5	1.1E-6	2.5E-4
3.1E-6	4.8E-4	70.5	1.6E-6	3.3E-4	114.5	1.4E-6	6.0E-5
1.3E-5	1.4E-3	71.5	7.8E-7	4.2E-5	115.5	1.7E-6	8.5E-5
6.8E-6	2.3E-3	72.5	3.5E-7	3.0E-5	116.5	2.0E-6	1.6E-4
5.1E-6	1.6E-3	73.5	4.5E-7	3.2E-5	117.5	1.2E-5	7.4E-4
6.6E-5	1.5E-2	74.5	5.7E-7	3.5E-5	118.5	3.0E-6	2.0E-4
1.5E-5	9.6E-4	75.5	1.2E-6	5.0E-5	119.5	1.1E-5	9.1E-4
1.2E-7	1.1E-3	76.5	2.9E-6	1.2E-4	120.5	4.5E-5	6.0E-3
1.3E-6	1.3E-3	77.5	2.9E-6	1.4E-4	121.5	2.0E-3	5.3E-2
1.0E-5	8.7E-4	78.5	4.5E-6	1.7E-4	122.5	1.8E-5	7.0E-3
4.2E-6	4.5E-4	79.5	3.2E-6	1.2E-4	123.5	1.3E-5	2.7E-4
1.3E-5	1.6E-3	80.5	1.8E-6	8.7E-5	124.5	1.0E-5	2.0E-4
4.7E-7	1.6E-4	81.5	2.1E-6	1.1E-4	125.5	1.1E-5	2.2E-4
4.9E-7	9.0E-5	82.5	2.5E-6	1.3E-4	126.5	1.4E-5	2.6E-4
5.7E-7	6.8E-5	83.5	8.2E-6	3.2E-4	127.5	7.7E-6	1.5E-4
1.9E-6	3.1E-4	84.5	3.4E-6	2.2E-4	128.5	6.4E-6	1.3E-4
2.9E-7	1.1E-4	85.5	4.1E-6	2.5E-4	129.5	9.9E-6	3.0E-4
4.3E-7	6.4E-5	86.5	4.9E-6	3.5E-4	130.5	3.4E-5	9.0E-4
2.4E-6	3.3E-4	87.5	5.8E-6	3.2E-4	131.5	9.7E-6	2.4E-4

3.2.4.3.1 Out of Band Rejection

The out-of-band rejection **shall** be such that < 10% of the observed signal comes from out-of-band for a typical solar spectrum.

If the out-of-band signal is greater than 10%, then a means of measuring and tracking this out-of-band signal **shall** be provided.

3.2.4.3.2 Long-term Stability

Over the duration of the mission, the EUVS instrument response **shall** change by less than 5% (Goal: <2%).

If the sensitivity is expected to change by more than 5% during the life of the mission, then a means of measuring and tracking the signal change **shall** be provided.

3.2.4.3.3 Flux Resolution and Response

The maximum size of each step in the flux measurement **shall** be 0.25% of specified full scale.

3.2.4.3.4 Wavelength Response

The wavelength response of each channel **shall** be measured to an accuracy of ±5%.

The instrument **shall** be calibrated at sufficient wavelengths to adequately characterize the wavelength response.

3.2.4.3.5 Measurement Accuracy

The accuracy of the EUV flux products **shall** be within ±10% of the actual flux (Goal: ±5%).

3.2.4.3.6 Signal to Noise

The signal level **shall** be such that at minimum (threshold) flux levels, the mean signal **shall** be greater than the standard deviation of the data (instrumental noise) over a 10 minute interval.

3.2.4.4 Electron Environment

The minimum performance of the EUV sensor **shall** not be compromised by the presence of the anticipated worst case natural electron environment.

To allow for the fact that the trapped particle population is not isotropically distributed, a 2% peak-to-peak sinusoidal variation with angle **shall** be assumed superimposed on the average electron environment. The representation for the worst case natural environment assumes isotropic flux with the spectral distribution shown in Assumed Worst-Case Electron Environment Table.

Assumed Worst-Case Electron Environment

E (MeV)	0.3	0.45	1.05	1.9
J(>E) (p cm^{-2} sec^{-1})	2×10^7	7×10^6	7×10^5	1.5×10^5

3.2.4.5 Temporal Resolution

A measurement of the solar flux **shall** be obtained every 30 seconds (Goal: 10 seconds).

The data latency, from the completion of image integration to the transmission of the last image bit to the spacecraft data bus, **shall** be no more than 5 seconds (Goal: 3 seconds). (TBR)

3.2.4.6 Spatial Coverage

The instrument **shall** provide a measurement of the disk integrated flux from the full solar disk and the lower solar atmosphere (Diameter of 40 arc-min centered at sun-center).

3.2.4.7 In-flight Calibration

A calibration mode **shall** be provided by ground command for determining electronic processing gain to an accuracy of 2% and for verifying basic instrument functionality.

This calibration **shall** be traceable to incident flux through detector preflight calibration.

The in flight calibration **shall** be both self-terminating and able to be terminated by ground command.

3.2.4.8 Pre-Flight Calibration

The complete EUVS **shall** be calibrated for sensitivity to EUV flux at a facility with an EUV source traceable to the NIST Standard for EUV calibration.

3.2.4.9 Pointing Accuracy and Angular Response

The instrument response, including the combined effect of spacecraft pointing and sensitivity variations across the sensor field-of-view, **shall** not deviate by more than 5% (goal 2%) for point sources of constant flux within 20 arc-min of the solar disk center.

3.3 Design Requirements

3.3.1 Reliability

The SIS **shall** have Reliability (R) of at least 0.6 after 10 years of on-orbit operations, preceded by up to 5 years of ground storage and up to 5 years of on-orbit storage.

The SIS **shall** have a Mean Mission Duration (MMD) of 8.4 years for a design life of 10 years.

The SIS **shall** withstand without damage the sudden removal of operational power.

3.3.2 Mechanical Requirements

Each SIS unit structure **shall** possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements.

3.3.2.1 Design Limit Loads

The structure **shall** be capable of withstanding all limit loads without loss of any required function.

Limit loads are defined as all worst case load conditions including 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 and on-orbit operations and storage.

3.3.2.2 Non-linear Loads

The SIS structures **shall** be capable of withstanding redistribution of internal and external loads resulting from non-linear effects including deflections under load.

3.3.2.3 Yield Strength

The SIS structures **shall** be able to support yield loads without detrimental permanent deformation. Yield loads are limit loads multiplied by the appropriate protoflight yield factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype yield factor of safety is 1.4.

While subjected to any operational load up to yield operational loads, the resulting deformation **shall** not interfere with the operation of the SIS flight units. Operational load is defined as the expected on-orbit loads while the SIS is operating.

3.3.2.4 Ultimate Strength

The SIS structures **shall** be able to support ultimate loads without fracture or collapse for at least 3 seconds including ultimate deflections and ultimate deformations of the flight unit structures and their boundaries. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Ultimate loads are limit loads multiplied by the appropriate protoflight ultimate factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype ultimate factor of safety is 1.6.

3.3.2.5 Structural Stiffness

Stiffness of the SIS structures and their attachments **shall** be designed by consideration of their performance requirements and their handling, transportation and launch environments.

Special stowage provisions **shall** be used if required to prevent excessive dynamic amplification during handling, transportation and transient flight events.

3.3.2.6 Unit Stiffness

The fundamental resonant frequency of the SIS **shall** be 50 Hz or greater when the flight unit is rigidly constrained at its spacecraft interface and the SIS is in its launch configuration.

3.3.2.7 Material Properties

Material properties **shall** be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.

Design values **shall** account for the probability of structural failures and loss of any required function due to material variability.

The instrument contractor **shall** specify the source and statistical basis of all material properties used in the design.

3.3.2.8 Critical Members Design Values

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

3.3.2.9 Redundant Members Design Values

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.

3.3.2.10 Selective Design Values

As an exception to Sections "Critical Members Design Values" and "Redundant Members Design Values", 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.

3.3.2.11 Structural Reliability

The strength, detailed design, and fabrication of the structure **shall** prevent any critical failure due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the SIS resulting in the loss of any mission objective.

Accounting for the presence of stress concentrations and the growth of undetectable flaws, the SIS structures **shall** withstand loads equivalent to four complete service lifetimes.

While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual SIS structures **shall** not interfere with the operation of the SIS.

After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures **shall** not interfere with the operation of the SIS.

3.3.2.12 Mechanisms

Deployment, sensor, pointing, drive, separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.

All SIS mechanisms **shall** meet performance requirements while operating in an earth gravity environment with any orientation of the gravity vector.

Moving mechanical assemblies **shall** have torque and force ratios per section 2.4.5.3 of GEV-SE using a NASA approved classification of each instrument mechanism.

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.

For all operating points of the actuators, all linear actuators **shall** have available a continuous maximum force output greater than 0.28 N.

For SIS 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.

All SIS mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.

All SIS mechanisms requiring restraint **shall** be released from a caged condition by command.

All SIS 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.

3.3.2.13 Pressurized Units

SIS pressurized systems **shall** follow the requirements in accordance with EWR-127-1 and MIL-STD-1522A for the design of pressurized systems.

The SIS **shall** have no open fluid reservoirs when delivered to the spacecraft contractor.

3.3.2.14 Alignment Reference

The SIS **shall** have a permanent flight worthy optical alignment reference composed of a minimum 2.54 cm alignment cube and a mounting surface datum.

The SIS **shall** have a flight worthy cover for the optical alignment cube.

The SIS sensor units **shall** have fiduciary marks locating the X, Y, and Z axes of the units.

3.3.2.15 SIS Unit Mounting

All SIS units, including sensors and electronics boxes, of any Flight Model **shall** be interchangeable, without modification, with the equivalent units of any other SIS Flight Model.

Each SIS unit **shall** be capable of being mounted or removed from the SIS mounting panel with the SIS mounting panel in the horizontal or vertical position.

For SIS units with a mass greater than 15 kg, a minimum of three lifting points **shall** be provided.

The design of the lifting points **shall** allow handling with an overhead crane including when the unit is in its flight configuration.

The SIS units **shall** be capable of being mounted or removed without the removal of other SIS units.

Each SIS unit design **shall** allow integration and de-integration to the SIS mounting panel while the panel is mounted to the spacecraft.

3.3.3 Thermal Requirements

3.3.3.1 Temperature Limits

The SIS contractor **shall** establish Mission Allowable Temperatures (MAT) for the SIS with at least 5 K of analytical/test uncertainty. Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.

The SIS **shall** maintain thermally independent units and their internal components within MAT limits during all flight operational conditions including bounding worst-case environments.

3.3.3.2 Non-Operational Temperature

The Non-Operational Temperatures (NOT) range **shall** extend at least 20 K warmer than the hot MAT and at least 20 K colder than the cold MAT.

The cold NOT **shall** be 248 K or colder.

3.3.3.3 Thermal Control Hardware

There **shall** be two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.

The SIS heaters **shall** be sized to have 25% margin for worst case conditions.

SIS survival heaters **shall** be thermostatically controlled.

3.3.4 On-board Processor Requirements

3.3.4.1 Flight Load Non-Volatile Memory

The entire flight software image **shall** be contained in non-volatile memory at launch.

3.3.4.2 Commandable Reinitialization

The Onboard Processor **shall** provide for reset by-command.

3.3.4.3 Deterministic Power-on Configuration

The Onboard Processor **shall** initialize upon power-up into a predetermined configuration.

3.3.4.4 Fail-safe Recovery Mode

The SIS **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.

3.3.5 Flight Software Requirements

3.3.5.1 Language and Methodology

All software developed for the SIS **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. Minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers with NASA approval.

3.3.5.2 Flight Software Upload

The flight software **shall** be reprogrammable on-orbit without computer restart.

The flight software **shall** be capable of being uploaded in Computer Software Units (CSUs) and is usable immediately after completion of the modified unit upload.

Activation of the modified CSUs **shall** not require completion of an upload of the entire flight software image.

3.3.5.3 Flexibility and Ease of Software Modification

The SIS flight software shall be deterministic in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.

All software data that are modifiable and examinable by ground operators **shall** be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.

The definition of instrument commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.

3.3.5.4 Verison Identifiers

All software and firmware versions **shall** be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.

This software identifier **shall** be keyed to the configuration management process.

3.3.5.5 Flight Processor Resource Sizing

During development, flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity):

Flight Processor Resource Utilization Limits

	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%
ROM Memory	50%	60%	70%
CPU	40%	50%	60%

3.3.5.6 Software Event Logging

The flight software **shall** include time-tagged event logging in telemetry.

The event messages **shall** include all anomalous events, mode transitions, and system performance events.

All flight software components **shall** utilize a common format for event messages.

The flight software **shall** provide a means for command to enable and disable queuing of individual event messages.

The flight software **shall** buffer a minimum of 1000 event messages while the event messages are queued for telemetering to the ground.

The 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.

The 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.

3.3.5.7 Warm Restart

The flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.

3.3.5.8 Memory Tests

The flight software **shall** provide a mechanism to verify the contents of all memory areas.

3.3.5.9 Memory Dump

The 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.

The flight software memory dump capability **shall** not disturb normal operations and instrument data processing.

3.3.5.10 Telemetry

Telemetry points sampled by the instrument shall be controlled by an on-orbit modifiable table.

The sample rate of every instrument telemetry point shall be controlled by an on-orbit modifiable table.

3.3.6 Power Requirements

3.3.6.1 Power Regulators and Supplies

The SIS power regulators and supplies **shall** have a phase margin of greater than 35 degrees.

The SIS power regulators and supplies **shall** have a gain margin of greater than 20 dB.

3.3.6.2 Fuses

The SIS **shall** not contain fuses.

3.3.6.3 Test Connectors

The SIS **shall** have flight qualified covers for all test point connectors.

3.3.7 Magnetic Properties

The change in the magnetic field produced by the SIS sensor, electronics, or power supply modules **shall** be less than 30 nano Tesla peak-to-peak for any operating mode, up to a single low pass bandwidth of 1.0 Hz, in any axis when measured at a distance of 1 meter from any face of a module.

3.3.8 Spacecraft Level Ground Testing

The SIS **shall** accommodate operational testing in all modes and states for indefinite periods during Spacecraft level Thermal Vacuum in at least the following two orientations:

1) Spacecraft +Y axis aligned with the gravity vector and pointed down.
2) Spacecraft -X axis aligned with the gravity vector and pointed down.

3.3.9 Ground Support Equipment and Development Facilities

3.3.9.1 Electrical System Test Equipment

The Electrical System Test Equipment (ESTE) **shall** operate the SIS and ground support equipment during performance verification and calibration testing.

The ESTE **shall** simulate the spacecraft interface with power, clock pulses, command, and telemetry functions.

The ESTE **shall** include all test equipment necessary to operate and control the SIS in all phases of operation and test modes.

The ESTE **shall** generate and maintain command logs.

The ESTE **shall** limit check all health and safety data.

The ESTE **shall** capture and archive all raw SIS data.

The ESTE **shall** provide near-real time and off line data analysis of all SIS data necessary to determine the performance characteristics of the instrument.

The ESTE **shall** interface with the Spacecraft Ground Support Equipment at the Spacecraft Contractor's facility to extract SIS science and engineering data.

The ESTE **shall** prohibit hazardous or critical commands being sent to the SIS without operator verification.

3.3.9.2 Flight Software Development Environment

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.

The FSDE **shall** support all lifecycle activities (development, test, and validation) simultaneously.

The FSDE **shall** contain all items (software, databases, compilers, debuggers, etc.) needed to prepare flight software for the target processor.

The FSDE **shall** contain engineering (hardware) models of necessary glight hardware as well as dynamic software models comprising the remainder of the instrument and the necessary on-orbit environment.

3.3.9.3 Shipping Container

The SIS shipping container **shall** be compatible with shipment by air or air-ride van.

The SIS shipping container **shall** be climate controlled and purgable.

The SIS shipping container **shall** have internal temperature, humidity, and pressure monitors with external indicators.

The SIS shipping container **shall** have shock recorders.

The SIS shipping container **shall** meet all contamination control requirements imposed on the SIS instrument units.

The SIS shipping container **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

The SIS GSE shipping containers **shall** be compatible with shipment by air or air-ride van.

The SIS GSE shipping containers **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

4 Acronyms

A/D	Analog to Digital
ACA	After Contract Award
AI	Action Items
AIR	Action Item Review
ANSI/ISO	American National Standards Institute / International Organization of Standards
CCP	Contamination Control Plan
CDR	Critical Design Review
cm	centimeter
CME	Coronal Mass Ejection
CMP	Configuration Management Plan
CMS	Configuration Management System
CPU	Central Processing Unit
CSU	Computer Software Unit
DEM	Differential Emission Measure
DOORs	Dynamic Object-Oriented Requirements System
ESD	Electro Static Discharge
ESTE	Electrical System Test Equipment
EUV	Extreme Ultra Violet
EUVS	Extreme Ultraviolet Sensor
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes Effects and Criticality Analysis
FMP	Financial Management Plan
FOV	Field of View
FPCCR	Formulation Phase Concept and Cost Review
FSDE	Flight Software Development Environment
FTA	Fault Tree Analysis
GIRD	General Interface Requirements Document
GOES	Geostationary Operational Environmental Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

Hz	Hertz
ICD	Interface Control Document
IR	Infra Red
IV&V	Independent Verification and Validation
K	Kelvin
MAID	Master Action Item Database
MAR	Mission Assurance Requirements
MAT	Mission Allowable Temperature
MeV	Mega Electron Volts
MLI	Multi Layer Insulation
MMD	Mean Mission Duration
MRD	Mission Requirements Document
MTF	Modulation Transfer Function
MTR	Midterm Review
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
nm	Nanometer
NOAA	National Oceanic and Atmospheric Administration
NOT	Non-Operational Temperature
PDR	Preliminary Design Review
PMP	Project Management Plan
PORD	Performance and Operational Requirements Document
PR	Progress Review
PRA	Probabilistic Risk Assessment
R	Reliability
RA	Recommended Approach
RAM	Random Access Memory
RFA	Request for Action
RFI	Request for Information
RMP	Risk Management Plan
ROM	Read Only Memory

SCOR	Solar Coronagraph
SCOR-GS	SCOR Ground System
SDP	Software Development Plan
SEL	Single Event Latch-up
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process
SEU	Single Event Upset
SIS	Solar Imaging Suite
SIS-GS	SIS Ground System
SLOC	Software Lines Of Code
SOW	Statement of Work
SXI	Solar X-Ray Imager
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Specified
TDI	Time Delay and Integration
TRL	Technology Readiness Level
TS	Trade Study
UIID	Unique Instrument Interface Document
UV	Ultra Violet
VP	Verification Plan
XRS	X-Ray Sensor
XUV	Soft X-ray to EUV