417-R-SEISSPORD-0030

Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Space Environment In-Situ Suite (SEISS)

Performance and Operational Requirements Document (PORD)

DRAFT
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National Aeronautics and Space Administration

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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) Space Environment In-Situ Suite (SEISS).

1.2. Mission Review

The SEISS particle sensors **shall** monitor the proton, electron, and heavy ion fluxes at geosynchronous orbit. These particle fluxes roughly consist of three components: 1) a geomagnetically trapped and highly variable population of electrons and protons; 2) sporadic fluxes of electrons, protons, and heavy ions of direct solar origin (e.g. from flares); and 3) a background of galactic cosmic rays ranging from several MeV to highly relativistic energies. Knowledge of the near-Earth energetic particle environment is important in establishing the natural radiation hazard to humans at high altitudes and in space, as well as risk assessment and warning of episodes of surface charging, deep dielectric charging, and single event upset of satellite systems. Energetic particle precipitation into Earth's ionosphere also causes disturbance and disruption of radio communications and navigation systems.

The SEISS particle sensors **shall** include a magnetospheric particle sensor (MPS), a solar and galactic proton sensor (SGPS), and an energetic heavy ion sensor (EHIS).

The SEISS objectives are as follows:

- Provide data essential to NOAA's Space Weather Operations and to the long-term record of changing conditions in the space environment.
- Maintain continuity with measurements provided in past and current Geostationary Operational Environmental Satellite (GOES) Series Spacecraft.
- Provide multiple measurements characterizing the charged particle population, including measurements of the electron, proton, and heavy ion fluxes.

1.3. Document Overview

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

1.4. Terminology

The term “(TBS)”, which means “to be specified”, means that the government 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.

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”.

The term “(TBD)” meaning “to be determined,” applied to a missing requirement means that the contractor should determine the missing requirement in coordination with the government.

1.5 Definitions

Throughout this document, the following definitions apply:

Accuracy: Refers to the error in a measurement, that 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.

All requirements/all performance requirements/ all operational requirements: Refers to any performance characteristic or requirement in the SEISS PORD, SEISS Unique Instrument Interface Document (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.

Eclipse: Defined as when the solar disk is completely occulted by the Earth or Moon, as viewed from the GOES satellite.

Flux: The number of particles crossing a unit area from a unit solid angle in a unit time. The directional-differential flux is given in units: $(cm^2\ s\ sr\ keV)^{-1}$ or $(cm^2\ s\ sr\ MeV)^{-1}$ and the directional-integral flux is given in units: $(cm^2\ s\ sr)^{-1}$.

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle. The duration of launch is expected to be less than 2 hours long.

Precision: Refers to the standard deviation of a statistically meaningful number of samples of a measurement.

Resolution: Refers to the standard deviation of a statistically meaningful number of samples of a measurement.

Station keeping: Inclination and East/West control.

TBD: Meaning "to be determined" is applied to a missing requirement. The missing requirement will be determined through the course of the contract execution.

TBR: Meaning "to be reviewed" implies that the requirement is subject to review for appropriateness by the contractor or the government. The government may change "TBR" requirements in the course of the contract.

TBS: Meaning "to be specified", indicates that the government will supply the missing information in the course of the contract.

Threshold: The minimum performance characteristic that is acceptable.

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.

Ultimate Load: Limit load multiplied by prescribed factors of safety.

Yaw Flip: The spacecraft interchanges North and South faces of the spacecraft as defined in section TBD of the GIRD.

1.6 Requirement Applicability

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

2. Applicable Documents

The following form a part of this specification to the extent specified herein.

SEISS Instrument Mission Assurance Requirements Document (IMAR), NASA GSFC, Document Number 415-R-SEISSMAR-00XX.

General Interface Requirements Document (GIRD), NASA GSFC, Document Number 417-R-GIRD-0009.

SEISS Unique Instrument Interface Requirements Document (UIID), NASA GSFC, Document Number 417-R-SEISSUIID-0031.

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-A83577B, 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.

3. Sensor Requirements

3.1. Sensor Definition

3.1.1. SEISS Modes

All SEISS modes and their functions **shall** be documented in the Interface Control Document (ICD).

The SEISS **shall** execute commands to individually enable and disable each autonomous function of the SEISS.

All SEISS instruments **shall** operate independently.

The SEISS **shall** provide telemetry that identifies the current mode of operation of the instrument. This telemetry **shall** be provided at the same rate as the instrument data.

The SEISS **shall** initiate all commanded mode transitions in no more than 20 seconds after receipt of command.

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

The SEISS **shall** transition from its current mode to any other mode without causing permanent damage to itself.

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

3.1.2.1 Safe Mode

The SEISS **shall** implement a Safe Mode.
The SEISS **shall** be in a thermally and optically safe configuration for an indefinite period of time while in Safe Mode.
The SEISS **shall** enter Safe Mode upon detection of internal faults capable of causing permanent damage to the instrument.

3.1.2.2 Normal Operational Mode

The SEISS instruments will conduct regular operations, while flying aboard a 3 axis stabilized, geostationary spacecraft with orbital limit constraints as stated in the SEISS GIRD and/or the SEISS UIID.

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

3.1.2.3 Instrument Diagnostic Mode

The SEISS **shall** implement an Instrument Diagnostic Mode.
The SEISS **shall** be in a fully functional configuration while in Instrument Diagnostic Mode.
In the Instrument Diagnostic Mode, the SEISS **shall**, as a minimum, perform the following:

- Download RAM contents.
- TBD

3.1.2. On-Orbit Operations

3.1.2.1. Reserved

3.1.2.2. Reserved

3.1.2.3. Eclipse

The SEISS **shall** be capable of continuous operation without reduction in performance during eclipse periods.

3.1.2.4. Operations After Maneuvers

3.1.2.4.1. Yaw Flip

The SEISS **shall** be in Normal Operational Mode while the spacecraft executes a yaw flip and after the spacecraft has executed a yaw flip.
The SEISS **shall** meet all performance requirements during and after a yaw flip.

3.1.2.4.2. Stationkeeping

The SEISS **shall** be in Normal Operational Mode while the spacecraft performs stationkeeping maneuvers.
The SEISS **shall** meet all performance requirements while the spacecraft performs stationkeeping maneuvers.

3.1.2.5. Activation

The instruments **shall** be fully functional within TBD days from launch.
The SGPS and EHIS **shall** be turned on within TBD minutes following launch.
The SEISS **shall** meet all requirements within 30 minutes of SEISS turn on.

3.1.2.6. Transfer Orbit

The SEISS **shall** be in Normal Operational Mode during transfer orbit. The instruments **shall** be turned on no less than TBD hours after launch.

3.1.2.7. On-Orbit Storage

The SEISS **shall** be in Normal Operational Mode during on orbit storage.

3.2. Sensor Characteristics

3.2.1. General Requirements

The requirements in this section apply to all instruments of the SEISS.

3.2.1.1. Noise

For bands below 30 keV, the total instrument noise (including that from the detector, background, and electronics) **shall** not exceed 10% of the energy resolution. For bands with threshold energies between 30 keV and 100 keV, noise **shall** not widen the effective response by more than 10 keV. For bands above 100keV, noise **shall** not widen the effective response by more than 10% of a band’s threshold energy.

3.2.1.2. Stability

The individual electronic discriminator levels defining the energy band upper and lower edges **shall** not change by more than 3% over the predicted operating conditions.

3.2.1.3. In-Flight Calibration

The instruments **shall** have an in-flight calibration mode. This mode **shall** verify basic instrument operation and determine the value of the energy band edges. Electronic discriminator levels **shall** be determined to ±3%.
The in-flight calibration **shall** be both self-terminating and able to be terminated by ground command.

3.2.1.4. Ground Calibration

The instruments **shall** be fully characterized prior to delivery, including the measurement of the instrument response to in-band (including direction, energy, and species) and out-of-band particles.

The energy dependent and the directional responses of the instruments **shall** be determined for energies ranging from below the detector's low-energy threshold to energies for which the particle flux is below the instrument detection threshold.

3.2.1.5. Out-of-Band Response

The response of the data channels to out-of-band particles (including direction, energy, and species) **shall** not exceed 10% of the response to in-band particles. Correction algorithms for the out-of-band response may be provided if necessary to comply with this requirement.

3.2.2. MPS Requirements

3.2.2.1. Low Energy Electrons and Protons

3.2.2.1.1. Flux Measurement Range

The MPS **shall** provide low energy electron and proton flux measurements in the range 30 eV to 30 keV.
The MPS **shall** determine the proton and electron flux in 15 evenly spaced logarithmic energy bands per species.

3.2.2.1.2. Accuracy

The MPS **shall** have a flux measurement accuracy of 10%, determined through ground calibration.

3.2.2.1.3. Spatial Coverage and Field of View

The MPS **shall** have at least five non-overlapping and equally spaced elevation bins (above and below the equatorial plane) spanning a total angle of 170° centered on either the Earthward or the anti-Earthward direction and symmetrical above and below the equatorial plane.

3.2.2.1.4. Data Rate

The refresh rate **shall** be at least once per 30 seconds.
The time from the end of data collection until the data is available at the spacecraft interface **shall** be less than 5 seconds. TBR

3.2.2.1.5. Maximum and Minimum Flux

The minimum flux must be detected with a minimum of 10 counts above background and a signal-to-noise ratio of 3 in each energy channel over a 5 minute interval.

The output **shall** not decrease as the flux increases up to three times the specified maximum flux.

a) Electrons

The MPS **shall** be able to measure the electron flux according to the following energy spectra (*E* is the energy in keV):

Minimum flux: Flux [cm^{-2} s^{-1} sr^{-1} keV^{-1}] = $9. \times 10^{4}$ $E^{-1.3}$

Maximum flux: Flux [cm^{-2} s^{-1} sr^{-1} keV^{-1}] = 1.5×10^{9} $E^{-1.3}$

b) Protons

Minimum flux: Flux [cm^{-2} s^{-1} sr^{-1} keV^{-1}] = $40.$ $E^{-0.8}$

Maximum flux: Flux [cm^{-2} s^{-1} sr^{-1} keV^{-1}] = 1.1×10^{7} $E^{-0.8}$

3.2.2.2. Medium and high energy electrons and protons

3.2.2.2.1. Measurement Range

The MPS **shall** measure electron flux in the range of 30 keV to 4 MeV.
The MPS **shall** determine the electron flux in 10 evenly spaced logarithmic energy bands plus one integral channel for energies greater than 2 MeV.

The MPS **shall** measure proton flux in the range of 30 keV – 1 MeV.
The MPS **shall** determine the proton flux in 7 evenly spaced logarithmic energy bands.

3.2.2.2.2. Accuracy

The MPS **shall** have a flux measurement accuracy of 10%, determined through ground calibration.

3.2.2.2.3. Spatial Coverage and Field of View

The MPS **shall** have at least five non-overlapping and equally spaced elevation bins (above and below the equatorial plane) spanning a total angle of at least 170° centered on either the Earthward or the anti-Earthward direction and symmetrical above and below the equatorial plane.

3.2.2.2.4. Data Rate

The refresh rate **shall** be at least once per 30 seconds.

The time from the end of the data collection until the data is available at the spacecraft interface **shall** be less than 5 seconds. TBD

3.2.2.2.5. Maximum and Minimum Flux

The minimum flux must be detected with a minimum of 10 counts rounded to the nearest integer above background and a signal-to-noise ratio of 3 in each energy channel over a 5 minute interval.

The output **shall** not decrease as the flux increases up to three times the specified maximum flux.

a) Electrons

The MPS **shall** be able to measure the electron flux according to the following energy spectra (E is the energy in keV):

Minimum flux:
0.030– 4 MeV: Flux [$cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}$] = $1.2 \times 10^{7}\ E^{-2.8}$

Maximum flux:
0.030– 4 MeV: Flux [$cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}$] = $2.3 \times 10^{11}\ E^{-2.8}$

b) Protons

The MPS **shall** be able to measure the proton flux according to the following energy spectra (E is the energy in keV):

Minimum flux:
0.030– 1 MeV: Flux [$cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}$] = $8. \times 10^{2}\ E^{-1.8}$

Maximum flux:
0.030– 1 MeV: Flux [$cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}$] = $5 \times 10^{7}\ E^{-1.3}$

3.2.3. SGPS Requirements

3.2.3.1. Measurement Range

The SGPS **shall** provide proton flux measurements in the energy range from 1 MeV to >500 MeV.
The flux **shall** be determined in 10 evenly spaced logarithmic energy bands up to 500 MeV.

3.2.3.2. Accuracy

The SGPS **shall** have a flux measurement accuracy of 10%, determined through ground calibration.

3.2.3.3. Spatial Coverage and Field of View

The SGPS **shall** have a minimum of two look-directions with identical viewing geometries, both centered in elevation on the equatorial plane, with one centered in the eastward direction and one centered in the westward direction.

3.2.3.4. Data Rate

The refresh rate **shall** be at least once per 1 minute.
The time from the end of the measurement interval until the data is available at the spacecraft interface **shall** be less than 5 seconds. (TBR)

3.2.3.5. Minimum and Maximum Flux

The SGPS **shall** resolve the largest likely solar particle event. The spectrum for this event can be represented as (E is the energy in keV):

Minimum flux: Flux $[cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}] = 8. \times 10^{2}\ E^{-1.8}$

Maximum flux: Flux $[cm^{-2}\ s^{-1}\ sr^{-1}\ keV^{-1}] = 2. \times 10^{12}\ E^{-2.8}$

This minimum flux must be detected with a minimum of 10 counts rounded to the nearest integer above background and a signal-to-noise ratio of 3 in each energy channel over a 5 minute interval.

The output **shall** not decrease as the flux increases up to three times the specified maximum flux.

3.2.4. EHIS Requirements

3.2.4.1. Measurement Range

The EHIS **shall** provide flux measurements in the energy range from 10 MeV/nucleon to 200 MeV/nucleon. The EHIS **shall** detect and distinguish between the following mass groups: He, C-N-O, Ne-S, and the Fe group. The flux within each mass group **shall** be determined in 5 evenly spaced logarithmic energy bands within the specified range.

3.2.4.2. Accuracy

The EHIS **shall** have a flux measurement accuracy of 10%, determined through ground calibration.

3.2.4.3. Spatial Coverage and Field of View

The EHIS **shall** have one look direction, centered in the anti-earthward direction.

3.2.4.4. Data Rate

The refresh rate **shall** be at least once per 5 minutes.
The time from the end of data collection until the data is available at the spacecraft interface **shall** be less than 5 seconds. (TBR)

3.2.4.5. Minimum and Maximum Flux

The EHIS **shall** measure the heavy ion abundances during the largest likely solar particle event. The minimum and maximum fluxes within each of the four mass bands can be represented as (E is the energy in MeV):

Maximum Flux: Flux $[cm^{-2}\ s^{-1}\ sr^{-1}\ (MeV/nuc)^{-1}] = 5 \times 10^{4}\ (E/nuc)^{-2.3}$

Threshold:
Minimum Flux: Flux $[cm^{-2}\ s^{-1}\ sr^{-1}\ (MeV/nuc)^{-1}] = 1.1 \times 10^{-2}\ (E/nuc)^{-1}$

Goal:
Minimum Flux: Flux $[cm^{-2}\ s^{-1}\ sr^{-1}\ (MeV/nuc)^{-1}] = 2.7 \times 10^{-3}\ (E/nuc)^{-1}$

This minimum flux **shall** be resolved with a minimum of 10 counts rounded to the nearest integer above background and a signal to noise ratio of 3 in each energy channel over a 5 minute interval.

The output **shall** not decrease as the flux increases up to three times the maximum flux.

3.3. Design Requirements

3.3.1. Lifetime

The SEISS **shall** have a 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 operation during on-orbit storage.
The SEISS **shall** have a Mean Mission Duration (MMD) of 8.4 years for a design life of 10 years.
The SEISS units of any Flight Model **shall** be interchangeable, without modification, with the equivalent units of any other SEISS Flight Model.
The SEISS **shall** withstand without damage the sudden removal of operational power.

3.3.2. Mechanical Requirements

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

3.3.2.3. Yield Strength

The SEISS 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 SEISS flight units. Operational load is defined as the expected on-orbit loads while the SEISS is operating.

3.3.2.4. Ultimate Strength

The SEISS 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 SEISS unit 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 each SEISS flight unit **shall** be 50 Hz (TBR) or greater when the flight unit is constrained at its spacecraft interface.

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 SEISS resulting in the loss of any mission objective.

Accounting for the presence of stress concentrations and the growth of undetectable flaws, the SEISS 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 SEISS structures **shall** not interfere with the operation of the SEISS.

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 SEISS.

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 SEISS mechanisms **shall** meet performance requirements while operating in an earth gravity environment with any orientation of the gravity vector(TBR).

Moving mechanical assemblies **shall** have torque and force ratios per section 2.4.5.3 of GEVS-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 SEISS mechanisms using closed-loop control, gain and phase margins **shall** be greater than 12 dB, and greater than 40 degrees, respectively. The margins **shall** include the effects of the dynamic properties of any flexible structure.

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

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

All SEISS 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

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

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

3.3.2.14. Alignment Reference

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

3.3.3. Thermal Requirements

3.3.3.1. Temperature Limits

The SEISS contractor **shall** establish Mission Allowable Temperatures (MAT) for the SEISS 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 SEISS **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 Non-Operational Temperature **shall** be -25^{O} C 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 SEISS heaters **shall** be sized to have 25% margin for worst case conditions.

The SEISS survival heaters **shall** be thermostatically controlled.

3.3.4. On-Board Processors 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 On-Board Processor shall provide for reset by command of software.

3.3.4.3. Deterministic Power-on Configuration

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

3.3.4.4. Fail-safe Recovery Mode

The Instrument **shall** provide a failsafe recovery mode dependant on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.

In failsafe recovery mode the instrument **shall** be commandable to begin execution at a specified memory address.

3.3.5. Flight Software Requirements

3.3.5.1. Language and Methodology

All software developed for the SEISS instrument **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. Software Module Upload

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

The flight software **shall** be capable of being uploaded in modules, units, segments, and objects which **shall** be usable immediately after completion of an upload of the modified modules, units, segments, and objects.

Activation of the modified modules, units, segments, and objects **shall** not require completion of an upload of the entire flight software image.

3.3.5.3. Flexibility and Ease of Software Modification

The SEISS flight software design **shall** be flexible and table-driven.

The SEISS flight software scheduling and prioritization **shall** have rigid schedules to ensure 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. Version 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** capture all anomalous events, redundancy management switching of instrument components, mode transitions, and important system performance events.

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

The flight software **shall** provide a means for ground command to enable and disable queueing 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 SEISS power regulators and supplies **shall** have a phase margin of greater than 35 degrees.
The SEISS power regulators supplies across the spacecraft **shall** have a gain margin of greater than 20 dB.

3.3.6.2. Fuses

The SEISS **shall** not contain fuses.

3.3.6.3. Test Connectors

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

3.3.7. Magnetic Properties

The change in the magnetic field produced by the SEISS sensor, electronics, or power supply modules **shall** be less than 30 nanoTesla 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 SEISS **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 in the nadir direction.
2) Spacecraft –X in the nadir direction.

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 SEISS 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 SEISS 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 SEISS data.
The ESTE **shall** provide near-real time and off line data analysis of all SEISS 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 SEISS science and engineering data.
The ESTE **shall** prohibit hazardous or critical commands being sent to the SEISS 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 flight 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 SEISS shipping container **shall** be compatible with shipment by air or air-ride van.
The SEISS shipping container **shall** be climate controlled and purgable.
The SEISS shipping container **shall** hae internal temperature, humidity, and pressure monitors with external indicators.
The SEISS shipping container **shall** have shock recorders.
The SEISS shipping container **shall** meet all contamination control requirements imposed on the SEISS instrument units.
The SEISS shipping container **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

4. Acronyms

ACA	After Contract Award
AI	Action Item
AIR	Action Item Review
ANSI/ISO	American National Standards Institute / International Organization of Standards
AR	Acceptance Review
CCP	Contamination Control Plan
CDR	Critical Design Review
CMP	Configuration Management Plan

CMS	Configuration Management System
CPU	Central Processing Unit
dB	Decibel
DOORS	Dynamic Object-Oriented Requirements System
EHIS	Energetic Heavy Ion Sensor
ESD	Electro-Static Discharge
FMEA	Failure Mode Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis
FMP	Financial Management Plan
FPCCR	Formulation Phase Concept and Cost Review
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
IV&V	Independent Verification and Validation
MAID	Master Action Item Database
MAR	Mission Assurance Requirements
MAT	Mission Allowable Temperature
MeV	Mega Electron Volts
MLI	Multilayer Insulation
MMD	Mean Mission Duration
MPS	Magnetospheric Particle Sensor
MRD	Mission Requirements Document
MTR	Midterm Review
N	Newton
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NOT	Non-Operational Temperature
OAT	Out-Gassing Allowable Temperature
OBP	On-Board Processor
PDR	Preliminary Design Review
PMP	Project Management Plan
PORD	Performance and Operational Requirements Document
PR	Progress Review
PRA	Probabilistic Risk Assessment
RA	Recommended Approach
RAM	Random Access Memory
RFA	Request for Action
RFI	Request for Information
RMP	Risk Management Plan
ROM	Read Only Memory
S/W	Software
SDP	Software Development Plan
SEISS	Space Environment In-Situ Suite
SEL	Single Event Latch-up

SEMP	Systems Engineering Management Plan
SEP	
SEP	Systems Engineering Process
SEU	Single Event Upset
SGPS	Solar and Galactic Proton Sensor
SLOC	Software Lines of Code
SOW	Statement of Work
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Specified
TRL	Technology Readiness Level
TS	Trade Study
UIID	Unique Instrument Interface Document
VP	Verification Plan
WBS	Work Breakdown Structure